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CONTENTS.

INDEX.

104680°—17——2

104680°—17——3

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Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

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THE PEA APHIS WITH RELATION TO FORAGE CROPS.

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CONTENTS.

INTRODUCTION.

The periodic occurrence of the pea aphis (*Macrosiphum pisi* Kalt.) in unusual abundance on various leguminous crops, more especially red and crimson clovers, vetches, field and garden peas, and sweet peas, has placed it among the important injurious insects of the world, for it is almost cosmopolitan and more or less injurious wherever found. In Europe it has been the subject of numerous treatises, both from the systematic and economic viewpoints, and its identity has been much confused with other closely related species. In America it seems to have made its first appearance in destructive and noticeable numbers in 1899, although it is known to have been present here for at least two decades previous, and each year since 1899 this aphis has been recorded as injurious in one or more localities in the United States.

In the present paper we have attempted especially to settle the identity of the species, an important item from the economic standpoint, and to report our extended life-history investigations, together with a summary of all the important facts, both old and new, relative to the life economy of the species.

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SYNONYMY.

This aphis seems to have been first authentically described under the name *Aphis pisi* by Kaltenbach in 1843 (5),[1] although two years previous Boyer de Fonscolombe (3) described a species under the name *Aphis onobrychis*, which is still doubtfully considered synonymous with *pisi* as will be noted later. Kaltenbach placed Schrank's *Aphis ulmariae* as a synonym of *pisi*, although this arrangement on the part of that author is not comprehensible, since he was doubtless aware of its priority over *pisi*. In 1855 Koch (6) redescribed *pisi* and placed it in the genus Siphonophora, no mention being made of *ulmariae*, although in the appendix of this work (p. 328) Kaltenbach's remarks include the following:

Siph. gei Koch ist, nach Herrich-Schäffer's richtiger Vermuthung, meine *Aphis Pisi* Kalt. und *Aph. Onobrychis* B. de Fonsc. Der ältere Schrank'sche Name *Aph. Ulmariæ* verlangt jedoch von allen Dreien das Prioritätsrecht.

The name *pisi* was adopted by entomologists almost universally until comparatively recent years when *ulmariae* was more or less generally accepted.

In 1909 Dr. N. A. Cholodkovsky (9) published the results of his studies on *Siphonophora pisi* and related species, definitely settling the identity of *pisi*, and for the first time pointed out that the *Aphis ulmariae* of Schrank, which he here placed in the genus *Siphonophora*, could hardly be the *pisi* of Kaltenbach. He therefore concluded that three species had heretofore been confused with *pisi*, namely *Macrosiphum pisi*, which he had found on garden peas (*Pisum sativum*), sweet pea (*Lathyrus odoratus*) and Medicago; *M. ulmariae* auct., which occurs on meadow-sweet (*Spiraea ulmaria*); and *M. caraganae* Cholod. on *Caragana arborescens*, and gives biological and morphological differences to separate the three. Later, in the same year and in the same publication, Dr. A. Mordwilko (10) gives a lengthy treatise on this insect, which he calls *Macrosiphum pisi* Kalt., and the related species. Eight supposedly distinct species are considered and a table illustrating differences of the following species is given: *M. pisi*, *M. cholodkovskyi*, *M. portschinskyi*, *M. ononis*, *M. gei*, and *M. urticae*. Three species occur on *Spiraea ulmaria*, namely, the *ulmariae* of Schrank, which he considers as belonging to the genus Aphis; *M. cholodkovskyi*, a name given for the species referred to by Cholodkovsky and other authors discussing a Macrosiphum on *Spiraea ulmaria;* and *M. portschinskyi*, a new species. The author is evidently not settled on the identity of *M. ononis* Koch, although at the end of the paper he states that "apparently the last species (*ononis* Koch) must also be recognized as distinct." And, finally, *M. onobrychis* B. de Fonsc. is questionably placed as a synonym of

[1] Numbers (1 to 12) in parentheses refer to the Bibliography of European Literature, p. 55.

pisi. More recently has come a contribution from Prof. Fred. V. Theobald (11, 12) who considers *gei* and *ulmariae* as distinct species, thus corroborating the general conclusions of the two eminent Russian entomologists, Cholodkovsky and Mordwilko. Theobald separates these large green *pisi*-like Macrosiphums into two groups according to the structure of the tip of the cornicle: (1) Those with the tip imbricated, containing *pisi* Kalt., *loti* Theob., and *trifolii* Theob., and (2) the group of closely related species with the tip of the cornicle reticulated, including *ulmariae* Schr., *gei* Koch, and *stellariae* Schr. Further, he is of the opinion that *ononis* Koch is distinct from *pisi*. Our own studies lead us to follow Mordwilko's conclusions. Schrank's description of *Aphis ulmariae* certainly seems to indicate that he was dealing with a true Aphis and not a Macrosiphum.

In 1782 Moses Harris, in his "English Insects," (1), figures an aphis which he calls *Aphis pisum* and gives a nondescript description. Theobald (12) has placed this species as a synonym of *pisi*, but there is nothing excepting the specific name to link it with the aphidid under discussion and it must therefore be placed as a possible synonym of *pisi* but not in the sense of having priority.

In 1841 Sir Oswald Mosley (4) describes *Aphis lathyri* as follows:

8th Species: *Aphis lathyri*.—On the Sweet Pea beneath the leaves; colour green, becoming when old of a dark purple; antennæ longer than the body; abdomen acuminated, with tubercles nearly extending to the extremity.

There is little doubt but that this description referred to *pisi*, but even with two years' priority the name *lathyri* can hardly take precedence over the well-established name *pisi* and must be placed in the same category as Harris's *pisum*.

The correct name which should be adopted for this insect is still somewhat questionable, but at this distance we, in America, must follow largely the researches of European aphidologists. *M. pisi* Kalt. must for the present be considered as having priority, although further researches may prove *Aphis onobrychis* B. de Fonsc. to be identical, this species having two years' priority over *pisi*, as stated above. In this connection Mordwilko (10) says:

The same species of plant louse [referring to *pisi*] was apparently described two years earlier (1841) by Boyer de Fonscolombe and named *Aphis onobrychis*, having been found on *Hedysarum onobrychis*. However, it is still premature to regard these two names as synonyms.

Walker, Buckton, Ferrari, Schouteden, Theobald, and others have made *onobrychis* a synonym of *pisi* but none has given sufficient evidence to support this conclusion. Authors discussing a plant louse on pea under the name *ulmariae* doubtless had in mind *M. pisi*, since it seems to have been fully proven that the true *ulmariae* does not feed on the hosts recorded for *pisi*. Further, we must accept the interpretations of Cholodkovsky, Mordwilko, and Theobald that species heretofore considered as synonomous with *pisi*, namely *gei* Koch, *ulmariae* Schr., and *ononis* Koch, are good and distinct species and that *onobrychis* B. de Fonsc. is still a doubtful species.

Our own results published herein assure us of the identity of the pea aphis (*pisi* Kalt.) occurring in America and Europe. In America there seem to be only two names, originating here, which can properly be considered synonyms of *pisi* Kalt., namely *destructor* Johnson and *trifolii* Pergande.

The synonymy of *Macrosiphum pisi* Kaltenbach, as we now understand it, is as follows:

Macrosiphum pisi (Kaltenbach).
Aphis pisum Harris.
Aphis lathyri Mosley.
Aphis onobrychis B. de Fonsc.?
Aphis pisi Kaltenbach.
Siphonophora pisi Koch.
Siphonophora ulmariae Passerini (nec Schrank).
Nectarophora pisi Oestlund.
Nectarophora destructor Johnson.
Macrosiphum pisi Schouteden.
Macrosiphum trifolii Pergande.

IDENTITY OF THE SPECIES OCCURRING IN AMERICA.

Macrosiphum pisi was first reported in America by Cyrus Thomas in 1878, although this record has been incorrectly discredited by most subsequent authors. In 1900, following the first noteworthy outbreak of this pest in the United States, Johnson described the species as new, calling it *Nectarophora destructor.* The following year Sanderson reported studies to show that *destructor* is identical with *pisi* of Europe, basing his conclusions partly by comparison with specimens labeled *pisi* from Buckton. Evidently Buckton was confused on this species, since one of the species sent Sanderson was certainly not *pisi*, for the tips of the cornicles were reticulated, a character which separates *pisi* from many closely related forms. Doubtless this error on the part of Buckton led Sanderson to consider certain American species with reticulated cornicles as synonyms or varieties of *pisi*. In 1904 Pergande described a species under the name *Macrosiphum trifolii.*[1] We have had an opportunity to examine the type slide of *trifolii* Perg. and find it to be identical with *pisi*, and our determination has been verified by Mr. Pergande. Notes on the

[1] Prof. Fred. V. Theobald (Theobald, Fred. V. The British species of the genus Macrosiphum, Passerini, Pt. II. *In* Jour. Econ. Biol., v. 8, no. 3, p. 139, fig. 46, Sept. 29, 1913) has described a new species under the name *M. trifolii*, overlooking the fact that the name is preoccupied. We therefore propose for this species *Macrosiphum theobaldii* n. n. It is distinguished from *pisi*, according to Theobald, only by the usually paler green color, the absence of sensoria on antennal segment III of the wingless female, and relatively thicker antennæ, which are rather variable characters for this genus. Winged forms were not observed by Theobald. It is not improbable that this will prove to be *pisi*.

type specimens of *trifolii* are given in the descriptive paragraphs. Pergande listed a variety of hosts attacked by *trifolii*, and although we have not seen specimens other than the types which were collected on *Trifolium pratense*, we doubt the correctness of its occurring on such plants as strawberry, dandelion, wheat, and oats, food plants noted by Pergande.

Through the kindness of Dr. Albert Tullgren, of Sweden, Drs. Mordwilko and Cholodkovsky, of Russia, Prof. F. V. Theobald, of England, and Dr. G. Del Guercio, of Italy, we have been able to compare the American *pisi* with specimens from the foregoing countries and find them to be identical.

PAST HISTORY OF THE PEST AND ITS INJURIES.

IN EUROPE.

For at least a century the "green dolphin," as this insect is commonly known in England, has been a serious pest to peas, vetches, and clover. One of the earliest records of injury is that given us in 1815 by Kirby and Spence (2), who reported that in 1810 "the produce was not much more than the seed sown; and many farmers turned their swine into their pea fields, not thinking them worth harvesting. The damage in this instance was caused solely by the Aphis, and was universal throughout the kingdom, so that a supply for the navy could not be obtained."

In 1876 Buckton (7) writes that this insect "in some years is very destructive to the farm crops. It feeds on a large number of plants, but chiefly it infests the field pea, on the young shoots and leaves of which it clusters by thousands." Thus the pea aphis seems only to have been occasionally and locally injurious in England; but in 1885 that country suffered from a great plague of pea "lice," and this unusual abundance has been correlated with the slight precipitation during that year. In her report for 1885, Miss Ormerod (8) notes that this plant louse particularly damaged peas and vetch.

As has been stated by Mordwilko (10):

> In North Europe the pea louse lets itself be heard from only occasionally. For instance, Kaltenbach (1843–1872) and C. Koch (1857) mention nothing at all about damage by the pea louse. Only E. Taschenberg notes briefly that the pea louse is occasionally very injurious to peas on which it hinders the further growth of the tips of young runners.[1]

Quoting further from Mordwilko (p. 36):

> In Russia as in N. Europe field peas suffer only occasionally from pea lice, namely, when the latter succeeds to increase greatly by the time or before peas come into bloom * * *.

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[1] Taschenberg, E. L. Naturgeschichte der wirbellosen Thiere, die in Deutschland sowie in den Provinzen Preussen und Posen den Feld-, Wiesen- und Weide-Culturpflanzen schadlich werden. Bremen, 1865. Also under title: Die der Landwirthschaft Schädlichen Insecten und Würmer.

IN AMERICA.

Dr. Cyrus Thomas was the first to observe and record this species from America (1878, 1879). The authenticity of this record has been doubted by most writers, but we have examined the specimens used by Thomas in drawing up his description (Davis, 1913) and find them to be the *Macrosiphum pisi* of Kaltenbach. Thomas's specimens were collected in Illinois in 1878, which is indicative of its introduction into America some years previous, possibly as much as 10 or 15 years before. Subsequently and previous to 1899, *pisi* was reported by Oestlund (1886), Smith (1890), and Williams (1891).

Macrosiphum pisi, therefore, was introduced into America fully 20 years previous to its appearance in serious numbers and here we have a case analogous to that of the gipsy moth, which was present in this country for about 25 years before it became a pest (Chittenden, 1909a).

Although the losses attributed to this aphidid have been largely to garden peas, still certain other crops have been much injured by it, the actual damage, however, never being apparent as in the case of the garden pea. Among other crops field peas are frequently injured by *pisi*. As early as 1900 Dr. Chittenden (1900b) reported injury to this crop, grown for hay, in Virginia. Mr. G. G. Ainslie records the total destruction of a plat of Canadian field peas at Nashville, Tenn., as early as February 17, in 1911.

The first positive record of injuries to clover in America by this plant louse was noted by Mr. W. G. Johnson, who wrote in 1900 that "hundreds of acres of red clover have been destroyed by it [*M. pisi*]. In one instance, reported to me June 13, 1900, Mr. C. Silas Thomas, of Lauder, Frederick County, Md., stated that the pest had almost entirely ruined 65 acres of red clover. Many other cases of a similar nature were reported or observed by us." Dr. E. D. Sanderson (1900g) reports the occurrence of a plant-louse, presumably this species, which occurred in injurious numbers on crimson clover as early as 1890. In the same paper Sanderson says:

> One of our best farmers, Mr. Frank Bancroft, of Camden, Del., tells me that he has seen what he judges to be the same louse on crimson clover for at least six or seven years [that is, about as early as 1893].

In 1900 Prof. F. M. Webster (1900) observed this insect in abundance on red clover at Wooster, Ohio. Dr. J. W. Folsom (1909) reports injury to red clover in the following words:

> In 1903 the louse killed an immense amount of red clover and weakened much more in Dekalb County [Illinois]. * * * I found on the farm of Mr. A. E. Myers, at Millbrook, August 19, 80 acres of dead clover roots in one field. Not one root in a thousand showed any signs of life, and on the ground were thousands of the cast skins of the aphid. At cutting the lice had been such a nuisance that the men objected to handling the crop. After cutting the clover never revived. In neighboring fields

there were many bare spots where the aphid had killed the clover locally, and in the growing clover were many centers of new infestation, due doubtless to migrant winged females. All of the clover in that part of the country was more or less injured; not only old clover but also the first-year growth. Returning to the same region the following summer to see the consequences of the injury, I did not stay long, for it was hard to find a field of clover anywhere. The farmers reported that the clover had been "winter killed," to their surprise, since the winter had not been a severe one and the clover had often survived worse winters.

Mr. Harold Morrison (1912), discussing the abundance of this insect in Indiana, says:

Two years ago [1910] it was so common in many clover fields near the city [Indianapolis] that the clover remained on the ground for more than a week after cutting without showing signs of curing. The clover stems were so plastered with honeydew that the moisture could not evaporate from them.

We have seen clover fields in Indiana so badly infested that the plants would be covered with the so-called "honeydew," a sticky, sweetish fluid ejected by the aphis from the anus. Walking through such an infested field, one's trousers would appear green, so thickly would they be covered by the plant-lice, and ruined by the honeydew which covered the plants. While it is seldom that fields are killed outright as described by Dr. Folsom, there can be no doubt that the heavy infestations, which are so common, have a decided weakening effect on the plant and much of the winter killing of clover can be traced back to the depredations of the pea aphis. Most probably much damage to clover has been overlooked or attributed to other causes, for while a crop may be injured on large field crops such as clover the injury will be overlooked unless the field is almost killed outright, and subsequent effects, such as the weakening of the vitality of the plants, is too often attributed to "winter killing," as Dr. Folsom has pointed out. Especially may this species be a very dangerous clover pest if the weather conditions are favorable to aphides and a long dry spell retards the growth of the clover.

CHARACTER OF ATTACK.

This aphidid prefers the young tender leaves and stems of its host, but eventually it covers the entire plant. Garden and sweet peas, being succulent plants, are seriously attacked and readily succumb to the depredations of the aphides. Clover, particularly red clover, on the other hand, is able to withstand considerable injury, but, as has been noted, even this plant is not free from serious damage; in fact entire fields of clover are sometimes destroyed.

EFFECTS ON CATTLE OF FEEDING THEM INFESTED CLOVER.

We have no definite reports of injury to cattle by feeding clover hay which has been heavily infested with aphidids; indeed, we have been informed by cattle feeders that such clover, which has a slightly sweetish taste because of the honeydew covering it, is rather relished by cattle. Mr. Lawson Caesar (1911) reports that feeding cattle with infested vines was supposed by one farmer to be the cause of the death of some of his cattle, but there seems to be no proof and the conclusions were probably incorrect.

DISTRIBUTION AND ORIGIN.

As will be seen on the accompanying map (fig. 1), this aphidid is generally distributed over the United States and southern Canada, especially in the eastern half, where it is more or less destructive every year. It is likewise generally distributed throughout Europe. Theobald (12) reports this species from Natal, South Africa, and Dr. B. Das (in litt.) has found it plentiful in British India.

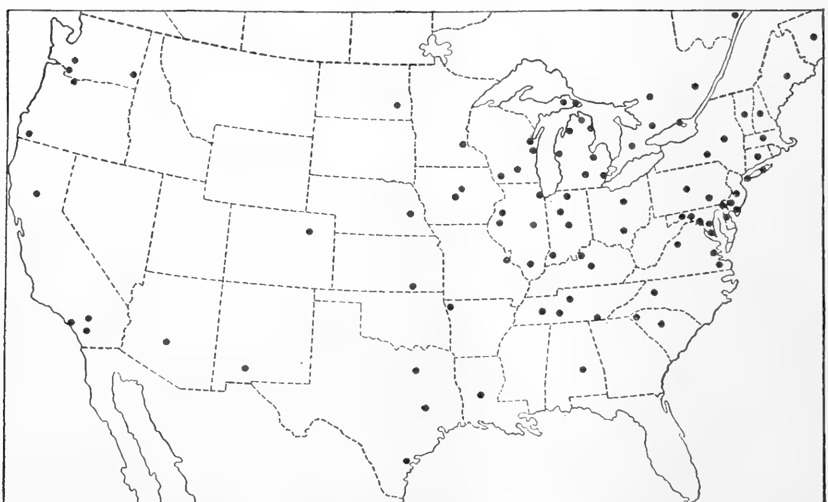

FIG. 1.—Map showing the known distribution of the pea aphis (*Macrosiphum pisi*) in America. (Original.)

As an injurious species it occurred first in America along the Atlantic coast. The following year (1900) it was very destructive in Wisconsin and Michigan, and has since worked its way westward to the Pacific coast. Recently Mr. F. C. Bishopp has sent in specimens from Texas, where it seems to have gained a strong foothold.[1]

The fact that *M. pisi* was first observed in this country within comparatively recent years and was first apparent in destructive

[1] Mr. Bishopp has kindly given the writer permission to quote his letter accompanying the specimens, under date of Aug. 4, 1914, which reads as follows:

> The pea aphis was observed to be doing damage to English peas (garden peas) in experimental plats just east of Dallas, shortly after the middle of May (1914). The peas began blooming about April 30. On May 26 the growth of the peas was practically stopped and many vines turned yellow on account of the exceedingly heavy infestation of aphides. On May 31 practically all of the pea vines were dead without having produced a single pod. During the first three weeks of June, lady beetles, principally *Hippodamia convergens*, were observed to be destroying the aphides in great numbers, and a few of the pea vines were almost cleared of the "lice" and started to grow a little; however, they never made any fruit.

Mr. Bishopp further stated that the sweet peas and garden peas throughout the city of Dallas were practically destroyed.

numbers only 15 years ago is evidence that it is of exotic origin, but further evidence of the fact that it is an introduced species may be obtained by a study of the origin of its host plants. Either the sexual forms or eggs of *pisi* have been found on alfalfa (*Medicago sativa*), *M. falcata*, red clover (*Trifolium pratense*), everlasting pea (*Lathyrus sylvestris*), *Lathyrus angustifolius*, and *L. latifolius*. All of these, according to De Candolle,[1] originated in Europe, Asia, or northern Africa; indeed, all of the known cultivated hosts of *pisi* had their origin in one or the other of these continents, and from what can be learned from other writers the uncultivated host plants as well are of exotic origin. Very probably the original host of *pisi* was one of the perennials, either *Medicago sativa* or *Trifolium pratense*, or perhaps *Onobrychis sativa*, if the aphis occurring on this plant should prove to be *pisi*. Of these three hosts *M. sativa* is supposed to be the oldest in cultivation, for, according to De Candolle, it has been cultivated for more than 2,000 years, while the other two have been in cultivation less than 2,000 years. From the fact that *M. sativa* is not universally and commonly attacked by *pisi*, while *T. pratense* is, we can with reasonable certainty assume that the latter was the original host of this legume aphidid. De Candolle has shown us that *T. pratense* is a native of Europe, Algeria, and western temperate Asia, while *M. sativa* is a native of western temperate Asia, and *Onobrychis sativa* originated in temperate Europe, south of the Caucasus. Speaking further of red clover he says:[2] "*Trifolium pratense* is wild throughout Europe, in Algeria, on the mountains of Anatolia, in Armenia, and in Turkestan, in Siberia toward the Altai Mountains, and in Kashmir and the Garhwal." Of alfalfa he says (p. 103): "It has been found wild, with every appearance of an indigenous plant, in several provinces of Anatolia, to the south of the Caucasus, in several parts of Persia, in Afghanistan, in Beluchistan, and in Kashmir."

From these we may assume with a fair degree of accuracy that *Macrosiphum pisi* originated in Europe or Asia, most probably in western temperate Asia or southeastern Europe.

FOOD PLANTS.

The pea aphis commonly feeds on the clovers—especially red and crimson clover—garden, grass, Canadian field, and sweet peas, vetch, and, as will be seen later, not infrequently on alfalfa. Shepherd's-purse (*Bursa bursa-pastoris*) has been repeatedly mentioned as a host, but experiments conducted by Mr. E. H. Gibson of the cereal and forage crop insect investigations, and our own tests, have given negative results. Further the writer has examined a number of different collections of Macrosiphum from this host, invariably

[1] Candolle, Alphonse de, Origin of Cultivated Plants, p. 468. London, 1884. [2] Loc. cit., p. 105.

labeled *M. pisi* or its equivalent, and in no case has the true *pisi* been found. On the other hand, Dr. Edith M. Patch had no difficulty in getting this insect to live contentedly on shepherd's-purse. Theobald (11) lists shepherd's-purse (*Bursa bursa-pastoris*) as a host, but later in his paper says: "Colonies now and then occur on the shepherd's-purse, but I have never known them to survive any length of time." The species reported for lettuce as *M. pisi* or a variety of that species by Sanderson and others is an entirely different plant-louse. Doubtless the species collected on nettle (Urtica) and referred to this species by Oestlund is something else, and the same can be said of the records of this aphidid from beet.

In 1900 Dr. Chittenden reported tests made by Mr. Theodore Pergande to colonize this insect on the following hosts, but with negative results in each case: *Sonchus asper*, dandelion, shepherd's-purse, *Sisymbrium officinale*, and dock.

Dr. Edith M. Patch (1911) has reported a series of insectary host-plant tests for *M. pisi*, which may be briefly summarized as follows: Transfers from peas (*Pisum sativum*) to potato (*Solanum tuberosum*), to barley, wheat, oats, purslane (*Portulaca oleracea*), beets, and squash were wholly negative; from peas to red clover partially positive, and from peas to shepherd's-purse (*Bursa bursa-pastoris*) positive.

During the late summer of 1911 Mr. C. W. Creel, of this bureau, and the writer conducted a number of transfer experiments, with the following results: From red clover to cowpeas, cultivated buckwheat, wild buckwheat (*Tiniaria cristata*), wild morning-glory (*Convolvulus arvensis*), fleabane (*Leptilon canadense*), pepper-grass (*Lepidium* sp.), wheat, alfalfa, yellow sweet clover (*Melilotus officinalis*), and cinquefoil (*Potentilla* sp.), the results were negative; from red clover to soy beans were partially positive and indicated that the insect might survive and reproduce on young tender plants; from red clover to red clover, garden peas, and white sweet clover (*Melilotus alba*) the insect transferred readily and fed and reproduced contentedly. In Chicago, Ill., we found it breeding very abundantly on tender succulent shoots of *Melilotus alba* growing under greenhouse benches.

Theobald (12) attempted to colonize the species on willow, raspberry, clematis, clover, and Lathyrus, but was successful with only the two last-named plants.

Mr. C. E. Sanborn (1904) reports this aphidid from rose, but in a recent letter he writes: "*Macrosiphum pisi* has been correctly recorded as being taken on rose. I doubt, however, if rose should be considered as a regular food plant of this insect." We have repeatedly attempted to colonize *pisi* on rose, but without success, and there seems to be no reasonable question but that the specimen collected by Sanborn on rose was a stray migrant.

Mr. D. T. Fullaway (1910) reports having taken *M. trifolii* Perg. (=*pisi*) on *Sonchus oleraceus* in Hawaii, but an examination of the specimens through the kindness of Mr. Fullaway shows them to be something other than *pisi*. We have also had the privilege of examining the specimens collected and recorded by Mr. W. M. Davidson (1909) as *M. pisi* on *Urtica holosericea*, and they prove to be of another species.

We have a number of individual office records reporting *M. pisi* on alfalfa. Among these, specimens for which were examined by the writer, are the following: Mr. C. N. Ainslie collected it on this host at Prairie Grove, Ark., March 21, 1907, all stages being found. An examination of this material shows a mixture of *M. pisi* and *M. creelii*, although the former species predominates. Mr. Ainslie also collected this aphidid at Arlington, Va., April 6, 1908, on alfalfa. Mr. V. L. Wildermuth collected it on alfalfa at Holtville, Cal., April 17, 1912, and at Muirkirk, Md., April 28, 1909. At the latter place the infested alfalfa had a wilted appearance, and because of their abundance this injury was supposed to be caused by the plant-lice. Probably the most noteworthy example of *pisi* occurring on alfalfa was recorded by Mr. J. A. Hyslop, who, on November 12, 1912, observed these aphides swarming in an alfalfa field near Funkstown, Md. At this time very few viviparous forms were observed; the males and oviparous females predominated, and a few days later the black shiny eggs were found abundant on the alfalfa leaves. In this same field Mr. Hyslop observed the aphides abundant in May (1913), but in August not a single individual was found. Further observations were made in this field by Mr. C. M. Packard in October (1913), at which time the aphides were again abundant. Mr. J. T. Monell has determined as this species plant-lice collected on alfalfa at Wellington, Kans., May 4 to July 30, 1909, by Mr. E. O. G. Kelly. In all cases where this aphidid occurred on alfalfa it was found on the young terminal buds and leaves.

The following is a list of the authentic hosts of *M. pisi* as recorded in America. Although shepherd's-purse is retained as a host of this plant-louse, we have never seen specimens of this species collected on that plant. Shepherd's-purse (*Bursa bursa-pastoris*), lentil (*Ervum* sp.), sweet pea (*Lathyrus odoratus*), grass pea (*L. sativus*), alfalfa (*Medicago sativa*), white sweet clover (*Melilotus alba*), garden pea and field pea (*Pisum sativum*), crimson clover (*Trifolium incarnatum*), red clover (*T. pratense*), white clover (*T. repens*), vetches or tares (*Vicia ludoviciana*, *V. gigantea*, *V. villosa*, et al.).

The following reliable hosts have been recorded by European writers. Many of the recorded hosts, such as Geum, Ulmaria, etc., are certainly incorrect, while others are highly improbable, and as they have not been corroborated since the correct identity of *pisi* has been understood, they are not here included: Shepherd's-purse

(*Bursa bursa-pastoris*), *Chaerophyllum sylvestre*, *C. temulum*, lentil (Ervum), *Lathyrus angustifolius*, sweet pea (*L. odoratus*), *L. latifolius*, *L. pratensis*, flat pea (*L. sylvestris*), *Medicago falcata*, alfalfa or lucern (*M. sativa*), *Onobrychis* sp. (?), *Ononis repens* et spp. (?), garden pea and field pea (*P. sativum*), *Trifolium filiforme*, alsike clover (*T. hybridum*), red clover (*T. pratense*), white clover (*T. repens*), vetch (*Vicia cracca*, *V. sativa*, *V. sepium*).

Dr. B. Das, of the Government college at Lahore, India, writes (*in litt.*) under date of December 18, 1913, as follows:

> I have collected it [*M. pisi*] from Bengal, Behar, United Provinces, and the Punjab. Though not actually collected by myself, I believe it is present in other parts of India as well. What looked like a bad attack on a few plants was observed once on that beautiful flower known as "Glory flower" or "Parrot's beak" (*Clianthus dampieri*). The hosts of this species, so far known to me besides the above are: *Alhagi maurorum*, *Melilotus alba*, *Medicago sativa*, *M. falcata*, *Lathyrus odoratus* (rather bad once in Behar), *Peganum harmala*, and *Dolichos lablab*.

DESCRIPTION.

STEM-MOTHER.

Young hatching from egg, before first molt and not over 24 hours old.—Body a very pale pea green and dorsum entirely covered with a fine and uniform whitish pulverulence which gives the insect a terre verte color. Head with a dusky patch on each side of the dorsal median line, which is, however, indistinct with the pulverulent covering. Eyes black. Antennæ four-segmented and blackish green, the last segment apparently black. Legs blackish green, the distal four-fifths of the hind tibiæ covered with a bloom giving them a whitish appearance and as if covered with a mold. Cornicles blackish green, slightly paler at the base and a black ring marking the rim of the opening at apex. Cauda not visible.

Measurements of a single individual, made immediately after mounting in balsam and before shrinkage occurs: Length of body, 0.956 mm., width, 0.487; length of cornicles, 0.0695 mm., width, 0.037; antennæ (the two antennæ measured exactly alike), segment I, 0.052 mm.; segment II, 0.043; III, 0.191; IV, base, 0.078; IV, filament, 0.178; total length, 0.542 mm.

Wingless adult (fig. 2).—(Described from four specimens, Apr. 24, 1913.) Body color pale green, the abdomen bearing several dark reddish dots which are the eyes of the embryos within her body. The dorsal and ventral surfaces show a distinct reticulation in living individuals, head bearing a faint pulverulence. Eyes dark red. Antennæ more than two-thirds the length of the body but not reaching to the base of cornicles; segments I and II concolorous with head and semitranslucent, the remaining segments semitransparent with a faint brownish green tint, excepting the tips of III and IV, distal fourth of V, distal half of VI, base and all of filament of VI, which parts are black; segment III sometimes, but not always, bearing a small inconspicuous sensorium near its base and the usual sensoria at distal end of V and VI base. Beak just reaching coxæ of second pair of legs. Legs with femur very pale green and semitransparent; tibia with basal half pale semitransparent, the distal half with a faint brownish tint and the tip black; tarsus black. Cornicles reaching tip of cauda (of the four specimens examined the cornicles reached a little beyond the tip of cauda in three specimens and not quite to the tip in the fourth specimen), concolorous with body at base, becoming paler and semitransparent toward the apex, the tip blackish; cylindrical and slender; noticeably widened at base and the tip imbricated. Cauda ensiform and typical of the genus, and concolorous with body.

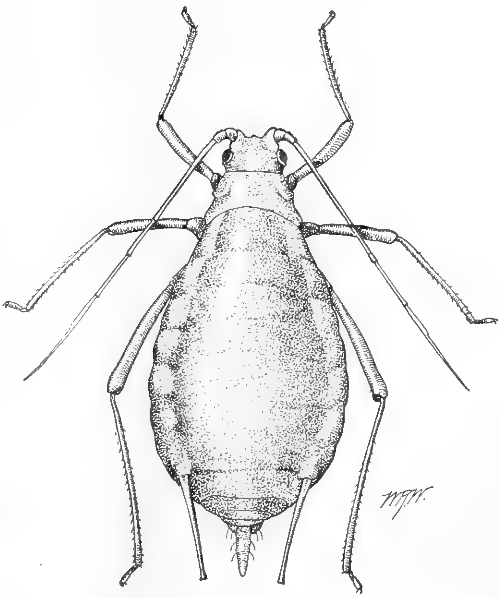

FIG. 2.—*Macrosiphum pisi:* Adult stem-mother. Much enlarged. (Original.)

Measurements from two specimens immediately after placing alive in balsam and before shrinkage occurs: Length of body, 2.63 mm., to tip of cauda, 3, width, 1.45; length of cornicles, 0.74 mm., of cauda, 0.44. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI, base.	VI, filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.156	0.069	0.695	0.348	0.469	0.235	0.522
.156	.078	.695	.348	.452	.243	.539
.139	.078	.626	.287	.400	.209	.469
.139	.087	.634	.296	.400	.209	.469

SUMMER VIVIPAROUS GENERATION.

First instar, before first molt and about 1 hour old (fig. 3).—(Described from six specimens, Aug. 20–21, 1912.) Head and thoracic segments whitish with a pale greenish tint; remainder of body pale green excepting those segments posterior to and including the segment bearing the cornicles, which are of a decided bright yellow tint. Antennæ five-segmented, reaching a little beyond tip of body, segments I and II concolorous with head or paler, the remaining segments whitish semitransparent with the tips of III, IV, and basal part of V dusky. Eyes bright red. Legs concolorous with antennæ, excepting tarsus which is dusky. Cornicles concolorous with antennæ the tip dusky, slightly narrowed at tip, and reaching beyond tip of abdomen. Style not visible.

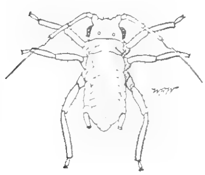

FIG. 3.—*Macrosiphum pisi:* First instar of viviparous generation. Much enlarged. (Original.)

Measurements from two specimens, immediately after placing in balsam and before shrinkage occurs: Length of body, 0.91 mm., width, 0.40; length of cornicles, 0.139 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V base.	V filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.06	0.05	0.19	0.18	0.087	0.39
.07	.05	.208	.208	.094	.45
.07	.05	.208	.208	.100	.45
.07	.05	.208	.208	.100	.45

Second instar, after first molt and 50 to 60 hours old.—(Described from four specimens, Aug. 19–22, 1912.) Entire body pale green; eyes red; antennæ reaching a little beyond tip of abdomen; segments I and II pale green and somewhat transparent; III, IV, and base of V pale, semitransparent, with the tips dusky; filament of VI blackish; segment III sometimes with a dusky ring near middle, but not constricted. Beak reaching coxæ of second pair of legs. Legs with femur very pale green, the tip dusky, tibia pale, becoming dusky toward tip, the tip blackish, and tarsus black. Cornicles pale, semitransparent, becoming pale dusky near apex, the extreme tip black. Cauda concolorous with body.

Measurements from two specimens, immediately after placing in balsam and before shrinkage occurs: Length of body, 1.16 mm., width, 0.53; length of cornicles, 0.25 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V base.	V filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.104	0.060	0.348	0.261	0.129	0.765
.095	.069	.330	.270	.139	.608
.104	.060	.348	.270	.139	.600
.095	.060	.348	.278	.139	.608

Third instar, after second molt and 75 to 97 hours old.—(Described from three specimens, Aug. 20–23, 1912.) Body pale green, the anterior portion, including head, slightly paler or yellowish green; some specimens pale yellow-green at posterior end, becoming whitish green toward anterior end. Eyes maroon red. Antennæ a little longer than body; 6-segmented; segment I pale green; II pale green, with a faint brownish tint; III, IV, and V pale, sometimes with a faint brownish tint, and the tips dusky to blackish; base of VI pale brownish to dusky, becoming blackish at the tip; filament of VI blackish. Beak reaching to coxæ of second pair of legs. Legs with femur pale greenish yellow to greenish, the apex sometimes pale brownish, tibia pale with a slight duskiness and the tip blackish, tarsus black. Cornicles reaching just to or a little beyond tip of cauda. Cornicles pale green to yellowish green at base, becoming pale dusky toward apex, the extreme tip black. Cauda concolorous with body. Cornicles, cauda, and antennæ usually semitransparent.

Measurements from one specimen, immediately after placing in balsam and before shrinkage occurs: Length of body, including cauda, 1.70 mm, width, 0.64; length of cornicle, 0.40 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.12	0.07	0.278	0.278	0.370	0.174	0.73
.12	.07	.268	.295	.382	.157	.73

Fourth instar, after third molt and between 127 and 128 hours old.—(Described from two specimens, Aug. 19–24, 1912.) Body pale green, sometimes with an indistinct yellowish area at the base of each cornicle, the head and thoracic segments sparsely covered with a whitish pulverulence which gives them a paler green color. Eyes maroon red. Antennæ reaching beyond tip of cauda; segment I concolorous with head, II concolorous with head or with a faint brownish tint; III, IV, V, and base of VI pale brownish green, with the tips blackish; filament of VI blackish. Legs with femur pale green at base, becoming faintly dusky toward apex, tibia pale brownish with tip blackish, tarsus black. Cornicles reaching a little beyond tip of cauda, pale green with the tip blackish. Cauda concolorous with body.

Measurements from one specimen, immediately after placing in balsam and before shrinkage occurs: Length of body, 2 mm., length including cauda, 2.25, width, 0.92; length of cornicles, 0.61 mm.; length of cauda, 0.25 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.15	0.07	0.487	0.469	0.504	0.208	0.887
.15	.07	.504	.452	.504	.208	.887

Adult wingless viviparous female.—(Described from four specimens reared on red clover, Aug. 18–22, 1912.) (Fig. 4.) Entire body pale gradually blackening toward tip; VI dark brown to black; segment green, the anterior part, including head and usually the first and second thoracic segments, as a rule paler. The red eyes of the embryos within the body are almost always visible through the dorsal body wall. As seen through the binocular the living individual appears slightly roughened and reticulated. Eyes dark reddish brown. Antennæ (fig. 4, *a*) on prominent tubercles; reaching beyond tip of cauda; filament of segment VI the longest, it being noticeably longer than III; segments I and II concolorous with head; III and IV dusky greenish to pale brownish, with the tips blackish; V darker, gradually blackening toward tip; VI dark brown to black; segment III with one or two, and sometimes three, circular sensoria near the base; segments V and base of VI with the usual distal sensoria; hairs short and sparse. Beak reaching to coxæ of second pair of legs. Legs long and slender, moderately hairy; femur pale green with a slight brownish tint toward apex, joint of femur and tibia dusky; tibia pale green, with a slight brownish tint, and the tip blackish; tarsus black. Cornicles long and slender, broadest at base, tip imbricated and no sign of reticulation, just reaching to tip of cauda, pale green at base, paler or with a faint brownish tint toward apex, the extreme tip black. Cauda concolorous with body, ensiform, and

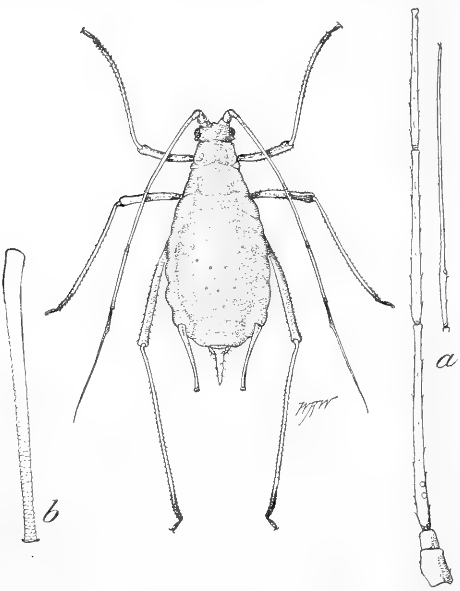

FIG. 4.—*Macrosiphum pisi:* Adult wingless female of viviparous generation, much enlarged; *a*, antenna, and *b*, cornicle, of same, more enlarged. (Original.)

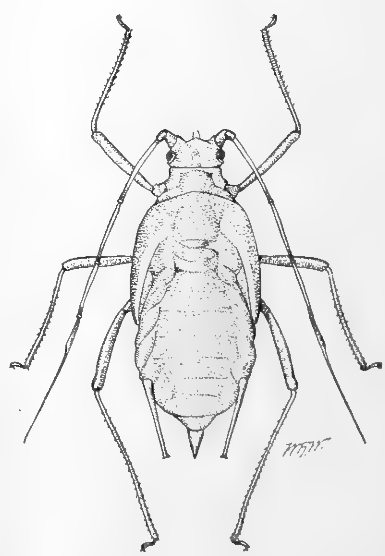

FIG. 5.—*Macrosiphum pisi:* Pupa of viviparous generation. Much enlarged. (Original.)

typical of the genus; more than half as long as the cornicles, bearing a number of moderately long hairs.

Measurements (averages) from three specimens, taken immediately after placing in balsam and before shrinkage occurs: Length of body, 2.67 mm., length to tip of cauda, 3.22; width, 1.24; cornicles, 0.98 mm.; cauda, 0.59 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI, base.	VI, filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.191	0.087	0.904	0.713	0.713	0.261	1.130
.191	.087	.930	.730	.713	.261	1.026
.191	.087	.817	.678	.696	.261	1.026
.191	.087	.800	.678	.626	.235	.974
.191	.087	.887	.696	.678	.261	.991
.174	.087	.870	.696	.696	.261	1.026

Pupa (fourth instar) (fig. 5).—(Described from three specimens, Aug. 22, 1912). Entire dorsum pale green, sometimes with a delicate white pulverulence. Wing pads pale greenish with faint brownish border, the tips darker brown. Underside of body with a distinct white pulverulence. Eyes maroon red. Antennæ with segments I and II concolorous with head; III, IV, and V pale with slight brownish tint and tips blackish; VI entirely blackish. Beak not reaching coxæ of second pair of legs. Legs with femur pale green, tibia pale with slight brownish tint and blackish at the tip, tarsus black. Cornicles pale green at base, becoming whitish with a faint duskiness, the tips black; cauda concolorous with body.

Measurements (average) from three specimens, immediately after placing in balsam and before shrinkage occurs: Length of body, 2.94 mm., width, 1.19; length of cornicles, 0.63 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI, base.	VI, filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.139	0.078	0.556	0.495	0.539	0.209	0.834
.139	.078	.539	.487	.548	.209	.852
.139	.069	.487	.469	.513	.209	.808
.139	.078	.461	.443	.487	.209	.817
.156	.078	.539	.522	.539	.209	.800
.148	.078	.556	.513	.565	.200	.887

Winged viviparous female (fig. 6).—(Described from three specimens reared on red clover, Aug. 22 and Dec. 11, 1912.) Head pale yellow-green, thoracic shield shining yellow-green, other parts of thorax concolorous with the head, and abdomen pale green with the eyes of the embryos showing through the skin of the dorsum as in the case of the adult wingless female. Eyes bright red. Antennæ (fig. 6, *a*) placed on large frontal tubercles, and reaching beyond tip of cauda;

filament of segment VI longest, it being noticeably longer than III; segments I and II of a darker green color than body, III with the extreme base pale, the remainder of that segment brownish with the extreme tip black; IV pale brown at base gradually changing to blackish brown toward the apex, the extreme tip black; V and VI blackish to black, bearing a moderate number of rather short, fine hairs; segment III with 11 to 22 (one apparently abnormal specimen had but 9 and 10 sensoria, respectively, on its two antennæ), with an average of 15.5 for 36 examples examined, circular sensoria arranged in a row but not extending quite to the tip, the distal one-fifth of the segment bare, the usual distal sensoria on V and base of VI. Beak

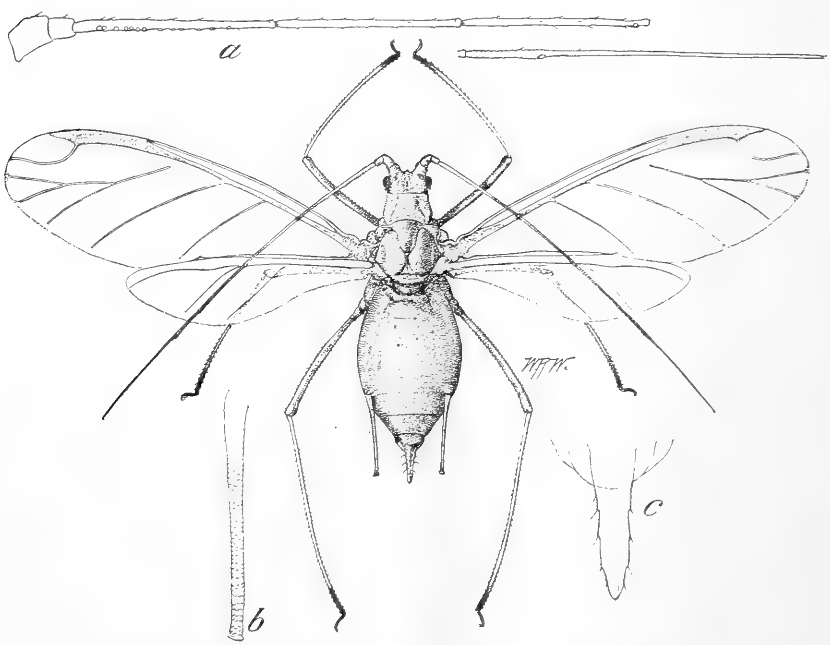

FIG. 6.—*Macrosiphum pisi:* Winged female of viviparous generation, much enlarged; *a*, antenna, *b*, cornicle, and *c*, cauda, of same, more enlarged. (Original.)

not quite reaching coxæ of second pair of legs. Wings clear, veins slender and brownish, the second branch of the media varying somewhat but usually about equidistant from tip of wing to the point where the media first branches; hind wings with normal venation. Legs long and slender; femur pale green on basal half, becoming dusky to blackish toward tip; tibia pale greenish with a faint brownish tint and the apex black; tarsus black. Cornicles (fig. 6, *b*) long and slender, reaching beyond tip of cauda, widest at the base, basal third concolorous with the abdomen, remainder dusky and the extreme tip black, imbricated, and no sign of reticulation at the tip. Cauda concolorous with the abdomen.

Measurements (average) from three specimens, immediately after placing in balsam and before shrinkage occurs: Length of body, 2.79 mm., to tip of cauda, 3.18., width, 1.11; length of wings, 3.51 mm., width, 1.16; length of cornicles, 0.84 mm.; length of cauda, 0.46 mm.; length of hind tibia, 2.32 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI, base.	VI, filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.156	0.069	0.826	0.721	0.748	0.304	1.095
.156	.078	.817	.730	.748	.296	1.061
....	....	1.006	.716	.735	.329	1.006
....	....	1.006	.677	.735	.310	.987
....	....	.968	.658	.658	.310	.968
....	....	1.045	.658	.677	.290	....

SEXUAL FORMS.

Winged male (fig. 7).—(Described from two specimens, Dec. 4, 1912.) Head and prothoracic segment gamboge with a dusky to

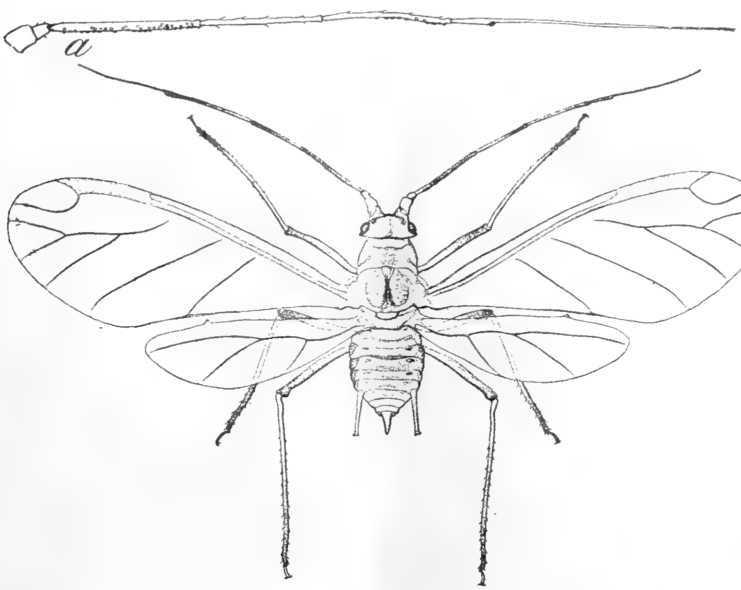

FIG. 7.—*Macrosiphum pisi:* Winged male, much enlarged; *a*, antenna of same, more enlarged. (Original.)

brownish longitudinal median dorsal marking which does not extend quite to tip of head. Thoracic shield brownish with interstices concolorous with head. Abdomen pale green with pale dusky markings as shown in the illustration (fig. 7) and the segments posterior to the cornicles pale yellowish green. Eyes very dark red, almost black. Antennæ (fig. 7, *a*) noticeably longer than body; filament of VI longer than III; entire antenna blackish excepting segments I and II and small area at base of III, which are pale dusky; sparsely covered with delicate, inconspicuous hairs; segment III bearing 40 to 50 irregularly placed circular sensoria, IV bare, V with 10 to 15 circular sensoria, not including the usual distal one, more or less in a row but more thickly placed toward the apex; base of VI with the usual distal ones. Beak whitish yellow, the tip black; reaching beyond the coxæ of the first pair of legs but not to the middle coxæ. Wings as in the viviparous female. Legs long and slender, the femur pale yellowish to yellowish green, becoming blackish on the distal third, tibia pale brown and the tip black, tarsus black. Cornicles as in viviparous forms, pale with a slight duskiness and the tip blackish. Cauda ensiform and bearing moderately long hairs as in other forms, and pale dusky to dusky in color.

Measurements of body dimensions not made from living specimens and mounted individuals are slightly shriveled. The male is considerably smaller than the viviparous female. Measurements from specimens mounted in balsam except as noted: Length of body, 1.4 mm., to tip of cauda, 1.55, width, 0.52; length of wing, 2.87 mm., width, 1.04; length of cornicle, 0.38 mm.; length of cauda, 0.20 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.156	0.069	0.696	0.539	0.626	0.217	[1] 0.852
.156	.069	.696	.547	.609	.243	[1] 1.008
.148	.069	.626	.435	.504	.217	[2] .852
.148	.069	.626	.400	.495	.191	[2] .800
.139	.069	....	.435	.469	.174	([2])

[1] Measured immediately after placing in balsam.
[2] Specimens killed in 70 per cent alcohol, mounted in balsam the following day, and measured immediately afterwards.

Wingless male (fig. 8).—(Described from two specimens, one observed in copula, October 18, 1911.) Head dusky brown, thoracic segments and first abdominal segment pale yellowish; remainder of abdomen pale green with dusky markings as follows: One spot on each side, dorsolateral in position, on the thoracic segments and the first five or six abdominal segments, those on the first two thoracic segments very faint, the others gradually larger, those on the first three abdominal segments being transverse markings rather than simple dots, and the markings on the following abdominal segments, dots or small circular spots. Antennæ situated on prominent frontal tubercles; much longer than the body; sparsely hairy; filament of segment VI longer than III; I and II dusky brown to blackish; III black, excepting paler extreme base; IV dark brownish and black at tip; V black, excepting a small portion at the base which is brownish, and VI black; segment III bearing 47 to 57 irregularly placed circular sensoria; IV bare; V with 14 to 18 circular ones, not including the usual distal sensorium, in a row on the distal two-thirds; base of VI with the usual ones. Beak reaching about to coxæ of second pair of legs. Legs long and slender, the femur blackish excepting basal third, which is pale; tibia pale brown except tip, which is black, and the tarsus black. Cornicles as in winged male, pale at base, becoming faintly dusky toward the tip; the apex black. Cauda pale green and agreeing with that of the winged male. Measurements (averages) from two specimens mounted in balsam, bodies slightly shriveled: Length of body, 1.55 mm., to tip of cauda, 1.72, width, 0.58; length of cornicles, 0.57 mm.; length of cauda, 0.26 mm. Measurements of antennal segments:

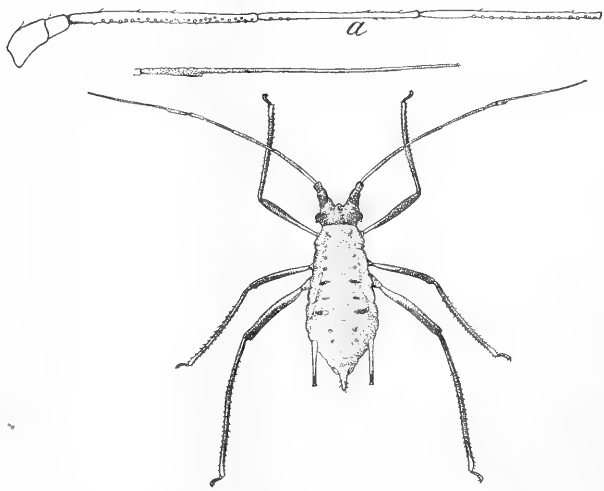

FIG. 8.—*Macrosiphum pisi:* Wingless male, much enlarged; *a*, antenna of same, more enlarged. (Original.)

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.156	0.087	0.817	0.713	0.748	0.252	1.061
.156	.087	.852	.678	.730	.261	1.009
.156	.087	.817	.651	.748	.269	.991
.156	.087	.817	.661	.739	.243	1.043

Wingless oviparous female (fig. 9).—(Described from two specimens, December 12, 1912.) General color pale pea green or even yellowish green, the head paler and the abdomen posterior to the cornicles with a yellowish tint in some individuals. The eggs within the body often show through the dorsal abdominal wall. Eyes dark red. Antennæ placed on prominent frontal tubercles; reaching to or a little beyond tip of body; very sparsely hairy; filament of segment VI longest; sensoria usually as in the wingless viviparous female, that is, only 1 or 2 sensoria at the base of segment III, but we have found exceptions where segment III bore as many as 10 sensoria in a row; segments I and II pale green or yellowish green, the remaining segments pale with a faint greenish tint and the tips of III, IV, V, and all the base of VI dusky and filament of VI black. Legs pale green, the tips of tibia and all of the tarsus blackish, basal two-thirds to three-fourths noticeably swollen and bearing numerous small circular sensoria (fig. 9*b*); cornicles as in other forms, just reaching to tip of cauda, pale with slight greenish tint and the tip dusky to blackish. Cauda pale green or yellowish. Measure-

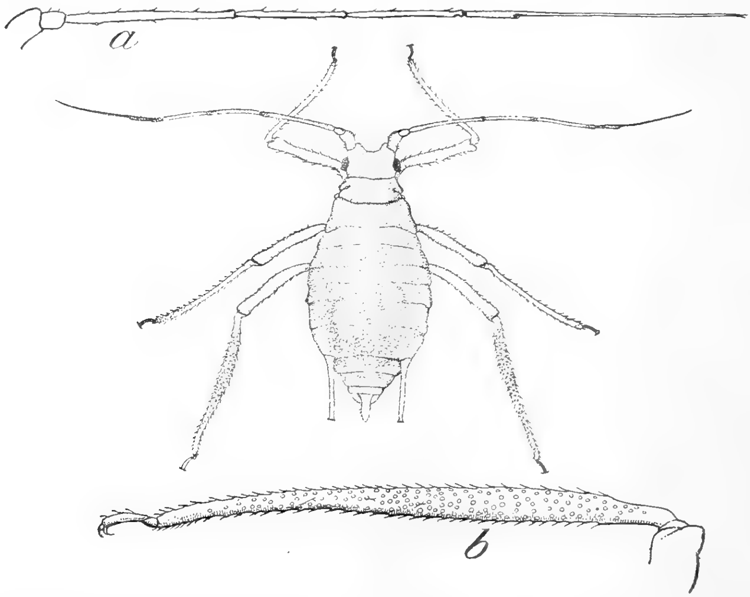

FIG. 9.—*Macrosiphum pisi:* Oviparous female, much enlarged; *a*, antenna, and *b*, hind tibia, of same, more enlarged. (Original.)

ments taken immediately after mounting: Length of body, 1.82 mm. (Another individual, apparently unfertilized, but with abdomen abnormally distended with eggs, measured 2.21 mm. in length and 1.28 mm. in width.) Length of body to tip of cauda, 1.97 mm., width, 0.93; cornicles, 0.46 mm.; cauda, 0.21 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.139	0.078	0.487	0.348	0.391	0.209	0.661
.139	.078	.494	.348	.400	.209	.643
.139	.078	.696	.435	.522	.234	.817
.156	.069	.748	.435	.522	.252	.800

Egg.—The egg is pale to bluish green and shining when first laid, gradually changing to jet black. It is elliptical oval, and measures 0.75 to 0.80 mm. in length and 0.35 to 0.40 mm. in width.

Sexuparæ.—What we have supposed to be wingless sexuparæ, that is, viviparous females which give birth to the sexual forms, differ from the summer wingless viviparous females only by a larger number of sensoria borne on antennal segment III. There is no positive assurance that these are sexuparæ but all of our mounted specimens showing this character were collected in September or later. Likewise, wingless viviparous females, collected in Russia during September by Dr. A. Mordwilko and sent us by Dr. N. Cholodkovsky, bear a similar number of sensoria. Six antennæ of specimens collected at La Fayette, Ind., in October bear 10, 7, 8, 9, 13, and 16 sensoria, respectively, on segment III, and eight antennæ of specimens collected in Russia in September bear 21, 22, 14, 7, 9, 9, 9, and 10 sensoria respectively, on segment III.

Aberrant form.—In the fall it is not uncommon to find a form which has the hind tibia swollen and bearing numerous sensoria, a character of the oviparous female, but instead of eggs the body often contains living young.

DESCRIPTIVE NOTES ON TYPE OF TRIFOLII PERG.

The type slide of *M. trifolii* Perg. which we examined September 5, 1911, bears the following data on label: "7205 (Nectarophora) Macrosiphum trifolii n. sp. Perg. on clover, Charlottesville, Va., Apr. 28, 1900." There are five winged viviparous females on the slide, the bodies of which are shrunken. The second branch of the median vein branches at a distance from the tip of the wing varying from one-half or less to three-eighths the distance from the tip to where it first branches, but usually the branching is nearer to the tip than to the point where the media first branches. Cornicles imbricated over their entire length but more distinctly near tip; the tip not reticulated. From the balsam specimens the tips of the cornicles appear to have been dusky in life, the remainder concolorous with body. Measurements of the antennal segments, cornicles, and cauda were taken as follows:

Antennæ.

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.156	0.069	0.678	0.556	0.574	0.243	Broken
.156	.078	.609	.522	.539	Broken	Broken
.156	.069	.626	.487	.504	.209	0.749
.148	.069	.591	.487	(1)	(1)	(1)
.156	.069	.731	.574	.582	.226	.801
.156	.069	.757	.609	.609	.226	----------
.174	.078	.835	.661	.661	.243	.836
.156	.069	.870	.661	.661	.261	.905
.156	.069	.661	.556	.591	.209	.731
.156	.069	.661	.556	.582	235	.818

[1] Not measureable.

Antennæ—Continued.

Cornicles.	Cauda.	Number sensoria on segment III.	Cornicles.	Cauda.	Number sensoria on segment III.
Mm.	*Mm.*		*Mm.*	*Mm.*	
0.556	0.348	13	0.697	....	12
.556	....	16	.749	0.383	14
.574	.313	12	.749	....	12
.591	....	13	.678	.400	14
.697	.417	15	.697	....	11

COMPARISON WITH THE EUROPEAN PISI.

After carefully comparing what is commonly known as *Macrosiphum destructor* or *M. pisi* in America with specimens labeled *pisi*, or its equivalent, from Russia, Sweden, England, and Italy, kindly sent us by Cholodkovsky, Mordwilko, Tullgren, Theobald, and Del Guercio, respectively, and with the complete descriptions of Mordwilko (10) and others, we can find no substantial difference and must conclude that the species occurring in Europe and America are identical. Measurements of European specimens of the wingless and winged viviparous, and wingless oviparous females, all taken from specimens mounted on slides in balsam, are given in Table I.

TABLE I.—*Measurements of European specimens of Macrosiphum pisi Kalt.*

WINGLESS VIVIPAROUS FEMALE.

Labeled—	Antennæ.								Length.		Wings.	
	I.	II.	III.	IV.	V.	VI. Base.	VI. Filament.	Number of sensoria on segment III.	Cornicles.	Cauda.	Length.	Width.
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*		*Mm.*	*Mm.*	*Mm.*	*Mm.*
Macrosiphum pisi Kalt. Wye, Kent, England, on peas 26-8-'11. F. V. Theobald	0.226	0.122	1.165	0.895	0.817	0.313	1.217	2	0.852	0.748	......	......
	.226	.122	1.165	.939	.835	.304	......	2	.817			
Siphonophora ulmariæ (=S. pisi Kalt.) Firenze, Italy, on Pisum sativum 8-6-1908. G. Del Guercio.	......	......	1.234	1.009	.835	.278	1.148	5	1.130	.713	......	......
	......	......	......	......	......	......	......	......	1.130			
Do	.191	.104	1.304	......	......	......	......	2	1.199	.739	......	......
	......	......	......	......	......	......	......	......	1.173			
Do	.243	.122	1.330	1.078	.878	.348	......	2	1.338	.782	......	......
	.226	.122	1.330	1.095	.869	.348	[1]1.304	3	......			
Do	......	......	([2])	([2])	([2])	.330	[1]1.304	4	1.078	.696	......	......
	......	......	1.286	1.086	.887	.313	1.338	3	1.113			
Macrosiphum ulmariæ (=M. pisi Kalt.). On Pisum arvense. Sweden. A. Tullgren	.226	.113	1.356	1.069	.878	.330	[1]1.200	3	1.200	800	......	......
	.226	.113	1.373	1.095	.921	......	......	5	......			
Siphonophora pisi Kalt. Pisum sativum, Esthland (Russia). N. Cholodkovsky	......	......	1.130	.939	.869	.304	1.156	3	1.252	.765	......	......
	......	......	1.208	.948	.869	.330	1.182	3	1.252			
Macrosiphum pisi Kalt. On Pisum sativum 1/14 VIII '09. Gouvern, Pskow, Russia. A. Mordwilko. Received from N. Cholodkovsky	......	......	1.165	.835	.800	.313	1.043	3	.835	......	......	......
	......	......	1.148	.800	.800	.296	1.043	2	.835			
Do	.226	.122	1.286	1.078	.965	.313	1.321	3	.974	.783	......	......
	.209	.113	1.252	1.043	.974	.313	1.286	3	.974			

[1] Tip shriveled.

[2] Measurements of segments III, IV, and V combined, 3.355 mm.

TABLE I.—*Measurements of European specimens of Macrosiphum pisi Kalt*—Contd.

WINGED VIVIPAROUS FEMALE.

Labeled—	Antennæ.								Length.		Wings.	
	I.	II.	III.	IV.	V.	VI. Base.	VI. Filament.	Number of sensoria on segment III.	Cornicles.	Cauda.	Length.	Width.
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*		*Mm.*	*Mm.*	*Mm.*	*Mm.*
Macrosiphum pisi Kalt. On sweet peas 20–9–'12. England. F. V. Theobald	0.191 .191	0.113 .113	1.069 1.060	0.930 .913	0.843 .852	0.313 .330	1.182 1.182	29 25	0.748 .765	0.539	4.41	1.62
Macrosiphum ulmariæ (=pisi Kalt). On Pisum arvense. Sweden. A. Tullgren	.208 .208	.113 .113	1.148 1.113	.991	.817	.321	....	21 21	.956 .904	.608	......	......
Macrosiphum pisi Kalt. On Pisum sativum, 1/14 VIII '09. Gouvern, Pskow, Russia. A. Mordwilko. Rec'd from N. Cholodkovsky	.208 .208	.104 .096	1.061 1.078	.913 .965	.817 .817	.313 .330	1.304 1.278	22 26	1.008 .991	.608	4.45	1.55
Macrosiphum pisi Kalt. On Lathyrus sp., Oct., 1903. Warschau, Russia. A. Mordwilko. Rec'd from N. Cholodkovsky	.174	.104	[1] 1.061	1.095	.904	.330	[2] 1.061	26	.782 .800	.556	......	......

WINGLESS OVIPAROUS FEMALE.

Macrosiphum pisi Kalt. On Lathyrus sp., Oct., 1903. Warschau, Russia. A. Mordwilko. Rec'd from N. Cholodkovsky	0.191 .191	0.104 .104	0.982 .956	0.721 .730	0.765 .756	0.295 .269	1.043 1.043	2 2	0.713	......	......	......
Do	.191 .191	.113 .104	1.113 1.130	.782 .765	.748 .748	.313 .295	1.061 1.061	2 4	.800	......	......	......

[1] Upturned, and measurements only approximate.

In no case, in specimens included in this table, were sensoria present on antennal segments IV and V, excepting the usual distal one on V; the cornicles were imbricated throughout, there being no reticulation at the tips. The hind tibiæ of the oviparous females bore numerous sensoria as is the case with specimens occurring in America. Figure 10, *a–d* were made from specimens collected by Dr. A. Mordwilko in Russia and sent us by Dr. N. Cholodkovsky.

We have not had an opportunity to examine specimens of the wingless or winged males from Europe but our specimens of the wingless male agree in every particular with the description given by Mordwilko (10).

LIFE HISTORY.

The life history of the pea aphis is quite simple, for it does not have a true alternate host like some species of plant-lice. As has been noted, it attacks leguminous plants primarily, some of which are annuals, others perennials. Clovers, particularly red and crimson clovers, serve as hosts for this insect the entire year, and it is on these plants that it usually passes the winter, either as eggs or as viviparous females, although during the summer months the migrants also pass to other leguminous crops, such as sweet pea, garden and field peas, and vetches, and on these they multiply very rapidly, oftentimes destroying large acreages. In the latitude of La Fayette, Ind., the species winters both as living viviparous females, usually wingless, and as eggs. Farther north it may winter exclusively in the egg stage, although our observations are not complete on this point,

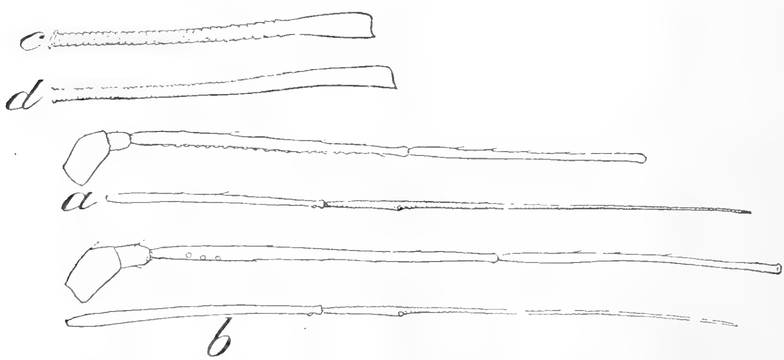

FIG. 10.—*Macrosiphum pisi* from Russia: *a*, antenna of winged viviparous female; *b*, antenna of wingless viviparous female; *c*, cornicle of winged viviparous female; *d*, cornicle of wingless viviparous female. Greatly enlarged. (Original.)

while farther south, in the latitude of Tennessee, the sexual forms which lay the overwintering eggs are rare, the insect ordinarily passing the winter as living plant-lice, both wingless and winged forms being able to withstand the lower temperatures in that latitude. Still farther south we know only the viviparous females and our observations lead us to believe that the species may reproduce viviparously indefinitely in localities where the winters are quite mild.

FIELD OBSERVATIONS.

In the latitude of Illinois, Indiana, Maryland, and Delaware migrants from the winter hosts, namely, red clover and crimson clovers, begin to spread to new fields of clover and to garden peas about May 1, and the injury to these crops usually becomes noticeable about June 1, extending up to July. Ordinarily by this time the parasitic and predacious enemies have become sufficiently numerous to control, or at least hold in check, the aphides, and a little later, usually depending on the climatic conditions, the aphidid fungus (*Empusa aphidis*) becomes prevalent, so much so, in fact, that the plant-lice are often apparently completely exterminated. However, as the weather conditions become more favorable for the aphis and less for the fungous disease and the aphidid parasites, the few survivors are soon able to cover the plants with their progeny, so that by September we ordinarily find them again abundant on clover and late garden peas.

Farther north the insect does not seem to appear in injurious numbers until later—that is, not until about July. The following records of injury for 1899 recorded by Dr. Chittenden (1900) illustrate this statement. The first record was for Gloucester County and Portsmouth, Va., on May 17; Maryland, May 23; Newark, Del., June 2; East Hampton, Conn., July 3; Long Island, N. Y., July 7: Orono, Me., July 28; Ontario and Nova Scotia, Canada, August 9.

GENERATION EXPERIMENTS.

We have carried on generation experiments with this species through two years (1912 and 1913) at La Fayette, Ind., and the following notes were made at La Fayette, except as indicated. The same general methods, as well as the cages and rearing shelters, heretofore used by the writer and described and figured in Technical Series Bulletin No. 25, Part II, of the Bureau of Entomology, have been adopted. The writer here expresses his appreciation of the services rendered by Messrs, C. W. Creel and A. F. Satterthwait, both of the Cereal and Forage Crop Insect Investigations, who attentively cared for the experiments during the absences of the writer in 1912 and 1913, respectively.

In 1913 eggs began to hatch on March 31 and from that date until January, 1914, there was obtained, out of doors, a maximum of 19 generations, no sexual forms being produced in the first-born generation series. On the other hand, following down "the last-born of the last-born" generation series, a minimum of 7 generations was obtained, the last generation consisting of males. The last generation, in this case, was really the twelfth generation from the egg, for a break in the first series of last-born generations made it necessary to substitute with the last-born of a later generation. Thus we obtained an average of 13 generations for the year. (See Table II.)

TABLE II.—*First and last generation series of Macrosiphum pisi from egg, March 31, 1913, La Fayette, Ind.*

Date.	Temperature.[1]		First-born generation series.																			Last-born generation series.											
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.
1913.	° F.	° F.																															
Mar. 31	56	?	a																														
Apr. 1	64	34	0																														
Apr. 2	75	45	0																														
Apr. 3	74	60	0																														
Apr. 4	62	41	0																														
Apr. 5	56	33	0																														
Apr. 6	55	29	0																														
Apr. 7	48	32	0																														
Apr. 8	47	33	0																														
Apr. 9	48	39	0																														
Apr. 10	61	46	0																														
Apr. 11	46	41	0																														
Apr. 12	41	37	0																														
Apr. 13	54	37	0																														
Apr. 14	62	35	0																														
Apr. 15	67	35	0																														
Apr. 16	71	30	0																														
Apr. 17	79	46	0																														
Apr. 18	80	48	0																														
Apr. 19	68	42	0																														
Apr. 20	66	35	0																														
Apr. 21	72	38	0																														
Apr. 22	83	47	0																														
Apr. 23	81	58	0																														
Apr. 24	81	61	2	b																													
Apr. 25	77	49	6	0																													
Apr. 26	56	41	1	0																													
Apr. 27	64	32	1	0																													
Apr. 28	53	40	0	0																													
Apr. 29	76	38	4	0																													
Apr. 30	83	43	3	0																													
May 1	90	48	6	0																													
May 2	89	53	6	0																													
May 3	87	58	8	0																													
May 4	82	62	4	0																													
May 5	83	63	7	0																													
May 6	84	54	5	0																													

May 7	66	42	0	3	b																											
May 8	71	45	2	5	0																											
May 9	74	53	2	6	0																											
May 10	62	36	2	2	0																											
May 11	57	35	2	1	0																											
May 12	70	42	4	4	0																											
May 13	82	53	3	11	0																											
May 14	83	60	5	8	0																											
May 15	87	62	4	10	0																											
May 16	87	49	1	6	0																											
May 17	76	50	2	6	0																											
May 18	79	48	2	4	0																											
May 19	72	50	2	6	0																											
May 20	76	56	3	7	0																											
May 21	82	63	0	7	7	b																										
May 22	82	52	1	4	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	b									
May 23	57	48	0	2	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
May 24	70	40	0	1	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
May 25	72	52	0	4	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
May 26	65	54	0	4	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
May 27	65	52	0	2	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
May 28	82	49	0	4	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
May 29	85	57	0	3	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
			88																													
May 30	87	64	....	3	7	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
May 31	80	62	....	5	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
June 1	82	65	....	3	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
June 2	79	59	....	3	5	7	b	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
June 3	79	61	....	0	4	7	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2									
June 4	82	54	....	0	3	8	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7									
June 5	76	56	....	0	3	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6									
June 6	90	62	....	0	5	11	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5									
June 7	91	55	....	0	3	6	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5									
June 8	59	44	....	0	3	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3									
June 9	64	(?)	....	0	1	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1									
June 10	66	44	....	0	1	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2									
June 11	74	45	....	0	3	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5									
June 12	82	45	....	0	1	8	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3									
June 13	85	52	....	0	1	6	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5									
June 14	91	54	....	0	2	7	4	b	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7									
				124																												
June 15	95	65	....	....	3	5	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4									
June 16	96	65	....	....	1	10	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7									
June 17	100	66	....	....	0	4	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3									
June 18	97	65	....	....	0	4	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7									
June 19	96	66	....	....	0	4	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2									

[1] The maximum and minimum temperature records are taken for the period represented between the hour of last observation and the hour of noted observation.
a=Date of hatching from egg.
b=Date of birth.

TABLE II.—*First and last generation series of Macrosiphum pisi from egg, March 31, 1913, La Fayette, Ind.*—Continued.

Date.	Temperature.		First-born generation series.																			Last-born generation series.											
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.
1913.	° F.	° F.																															
June 20	101	66			0	2	2	0															3										
June 21	95	70			0	3	4	0															4										
June 22	84	62			0	0	5	4	b														1										
June 23	75	63			0	1	2	5	0														1										
June 24	81	(?)			0	0	3	7	0														1										
June 25	83	72			0	0	3	5	0														6										
June 26	86	69			0	0	4	9	0														0										
June 27	93	71			0	0	2	4	0														0										
June 28	94	75			0	0	1	6	0														2	b									
					90	111																											
June 29	95	74					0	5	0														0	0									
																							92										
June 30	94	76					0	6	0															0									
July 1	94	75					2	6	4	b														0									
July 2	90	71					3	2	6	0														0									
July 3	90	73					3	4	4	0														0									
July 4	92	74					0	2	2	0														0									
July 5	93	74					0	3	5	0														0									
July 6	95	66					0	0	3	0														0									
							59																										
July 7	84	60						0	3	0														0									
								68																									
July 8	92	65							1	0														0									
July 9	94	66							1	0														0									
July 10	90	61							3	0														0									
July 11	85	57							3	0														0									
July 12	89	70							0	0														0									
July 13	88	63							3	0														0									
July 14	90	67							1	0														0									
July 15	94	70							0	0														0									
July 16	92	76							0	0														0									

July 17	95	75							0	0														0							
July 18	89	66							0	2	b													(1)							
									39																						
July 19	83	64								5	0																				
July 20	85	60								1	0																				
July 21	79	56								4	0																				
July 22	85	55								4	0																				
July 23	88	60								3	0																				
July 24	80	67								2	0																				
July 25	80	52								1	0																				
July 26	89	61								0	0																				
July 27	93	72								1	0																				
July 23	95	72								1	0																				
July 29	94	71								1	0																				
July 30	98	74								1	4	b																			
July 31	98	74								1	6	0																		b	
Aug. 1	95	66								1	2	0																		0	
Aug. 2	87	61								0	1	0																		0	
Aug. 3	90	61								0	2	0																		0	
										29																					
Aug. 4	94	67									4	0																		0	
Aug. 5	85	59									1	0																		0	
Aug. 6	89	63									5	0																		0	
Aug. 7	88	70									2	+																		0	
Aug. 8	92	73									1	5	b																	0	
Aug. 9	98	76									} 6		{ 0																	3	
Aug. 10	92	73											0																	1	
Aug. 11	86	68									0		0																	6	
Aug. 12	75	65									1		0																	1	
Aug. 13	84	71									2		0																	2	
Aug. 14	83	71									1		0																	3	
											38																				
Aug. 15	83	71											0																	5	
Aug. 16	91	74											3	b																3	
Aug. 17	95	73											3	0																3	b
																													27	
Aug. 18	91	73											7	0																	0
Aug. 19	87	72											5	0																	0
Aug. 20	83	67											8	0																	0
Aug. 21	90	72											3	0																	0
Aug. 22	90	68											6	0																	0
Aug. 23	75	58											4	0																	0
Aug. 24	81	55											5	0																	0
Aug. 25	73	55											5	3	b																1
Aug. 26	87	60											6	5	0																2

[1] Died before reproducing.

[b] Date of birth.

TABLE II.—*First and last generation series of Macrosiphum pisi from egg, March 31, 1913, La Fayette, Ind.*—Continued.

Date.	Temperature. Maximum.	Temperature. Minimum.	First-born generation series. First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	Last-born generation series. First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.
1913.	° F.	° F.																															
Aug. 27	92	69	...	...	...	...	...	...	...	...	...	...	3	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10		
Aug. 28	94	66	...	...	...	...	...	...	...	...	...	...	1	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3		
Aug. 29	94	53	...	...	...	...	...	...	...	...	...	...	4	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9		
Aug. 30	78	53	...	...	...	...	...	...	...	...	...	...	0	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2		
Aug. 31	82	62	...	...	...	...	...	...	...	...	...	...	2	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6		
Sept. 1	83	69	...	...	...	...	...	...	...	...	...	...	6	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6		
Sept. 2	97	67	...	...	...	...	...	...	...	...	...	...	0	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7		
Sept. 3	98	68	...	...	...	...	...	...	...	...	...	...	0	4	8	b	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3		
Sept. 4	98	69	...	...	...	...	...	...	...	...	...	...	0	3	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4		
Sept. 5	86	64	...	...	...	...	...	...	...	...	...	...	0	2	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4		
Sept. 6	91	70	...	...	...	...	...	...	...	...	...	...	0	7	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5		
Sept. 7	95	71	...	...	...	...	...	...	...	...	...	...	0	2	8	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6		
Sept. 8	92	64	...	...	...	...	...	...	...	...	...	...	0	1	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3		
													70																				
Sept. 9	96	53	...	...	...	...	...	...	...	...	...	...	...	1	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1		
Sept. 10	79	50	...	...	...	...	...	...	...	...	...	...	...	0	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1		
Sept. 11	85	57	...	...	...	...	...	...	...	...	...	...	...	2	6	5	b	...	...	...	...	...	...	...	...	...	...	...	...	...	1		
Sept. 12	90	61	...	...	...	...	...	...	...	...	...	...	...	1	2	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0		
Sept. 13	71	52	...	...	...	...	...	...	...	...	...	...	...	0	3	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0		
Sept. 14	70	48	...	...	...	...	...	...	...	...	...	...	...	0	5	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0		
Sept. 15	72	50	...	...	...	...	...	...	...	...	...	...	...	0	3	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	1	b	
Sept. 16	69	50	...	...	...	...	...	...	...	...	...	...	...	0	2	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	
Sept. 17	76	67	...	...	...	...	...	...	...	...	...	...	...	0	4	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	
Sept. 18	73	58	...	...	...	...	...	...	...	...	...	...	...	0	2	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	
																27															75		
Sept. 19	73	52	...	...	...	...	...	...	...	...	...	...	...	0	3	...	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	
Sept. 20	70	55	...	...	...	...	...	...	...	...	...	...	...	0	2	...	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	
Sept. 21	55	45	...	...	...	...	...	...	...	...	...	...	...	0	0	...	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	
Sept. 22	50	42	...	...	...	...	...	...	...	...	...	...	...	0	0	...	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	
Sept. 23	52	37	...	...	...	...	...	...	...	...	...	...	...	0	0	...	1	b	...	...	...	...	...	...	...	...	...	...	...	...	...	0	
Sept. 24	76	54	...	...	...	...	...	...	...	...	...	...	...	0	0	...	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	
Sept. 25	82	52	...	...	...	...	...	...	...	...	...	...	...	0	0	...	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	
Sept. 26	81	51	...	...	...	...	...	...	...	...	...	...	...	0	0	...	6	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	
Sept. 27	58	38	...	...	...	...	...	...	...	...	...	...	...	0	0	...	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	
														57																			

Sept. 28	76	45													0		3	0													0	
Sept. 29	68	56													0		6	0													0	
Sept. 30	80	57													0		5	0													0	
															73																	
Oct. 1	80	53															4	0													0	
Oct. 2	76	54															5	0													0	
Oct. 3	74	42															2	0													3	
Oct. 4	74	46															7	0													2	
Oct. 5	82	56															4	0													3	
Oct. 6	70	60															4	6	b												2	
Oct. 7	87	59															6	8	0												1	
Oct. 8	86	62															6	7	0												2	
Oct. 9	81	56															7	10	0												0	
Oct. 10	84	61															3	5	0												0	
Oct. 11	86	48															4	8	0												1	
Oct. 12	64	42															1	1	0												1	
Oct. 13	70	55															1	2	0												2	
Oct. 14	75	41															2	4	0												2	
Oct. 15	77	50															3	1	0												1	
Oct. 16	78	54															1	5	4	b											2	b
Oct. 17	68	59															4	5	5	0											1	0
Oct. 18	62	43															1	0	2	0											0	0
Oct. 19	59	39															0	1	0	0											0	0
Oct. 20	53	47															1	1	2	0											0	0
Oct. 21	49	30															0	0	1	0											0	0
Oct. 22	48	32															0	0	0	0											0	0
Oct. 23	44	39															0	0	0	0											0	0
Oct. 24	55	43															0	2	1	0											0	0
Oct. 25	62	38															0	1	2	0											0	0
Oct. 26	66	36															0	1	1	0											0	0
Oct. 27	69	41															2	3	1	0											0	0
Oct. 28	47	40															0	1	2	0											0	0
Oct. 29	49	39															0	0	0	0											0	0
Oct. 30	39	32															0	0	2	0											0	0
Oct. 31	50	28															0	1	0	0											0	0
Nov. 1	51	22															0	0	0	0											0	0
Nov. 2	54	28															0	1	0	0											0	0
Nov. 3	59	41															0	3	1	0											0	0
Nov. 4	58	34															0	2	3	0											0	0
Nov. 5	60	30															0	0	1	0											0	0
Nov. 6	68	32															0	2	1	0											0	0
Nov. 7	65	57															0	1	1	0											0	0
Nov. 8	65	34															0	1	0	0											0	0
Nov. 9	37	28															0		0	0											0	0
Nov. 10	32	24															0	1	0	0											0	0
Nov. 11	44	16															0		0	0											0	0
Nov. 12	62	31															0		0	0											0	0
Nov. 13	61	55															0			0											0	0
Nov. 14	61	44															0	...	1	0												(1)
Nov. 15	45	39															0			0											23	

[1] Winged males.

b Date of birth.

TABLE II.—*First and last generation series of Macrosiphum pisi from egg, March 31, 1913, La Fayette, Ind.*—Continued.

Date.	Temperature.		First-born generation series.																			Last-born generation series.											
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.
1913.	° F.	° F.																															
Nov. 16	42	38															0			0													
Nov. 17	52	38															0			0													
Nov. 18	64	47															0	2	10	0													
																	104																
Nov. 19	64	58																		0													
Nov. 20	67	58																7	6	0													
Nov. 21	68	56																3	0	0													
Nov. 22	71	60																0	2	0													
Nov. 23	77	42																0	0														
Nov. 24	49	34																0	0	3	b												
Nov. 25	65	33																0	0														
Nov. 26	50	42																0	0	4	0												
Nov. 27	51	46																0	0	2	0												
Nov. 28	57	48																0	0	3	0												
Nov. 29	57	55																0	0		0												
Nov. 30	59	55																0	1	4	0												
Dec. 1	59	51																0			0												
Dec. 2	60	52																0	0	7	0												
Dec. 3	56	50																0	0		0												
Dec. 4	51	38																0			0												
																		96	3	4	0												
Dec. 5	50	37																			0												
Dec. 6	58	41																	2	1	0												
Dec. 7	56	32																															
Dec. 8	32	19																	0	1	0												
Dec. 9	39	29																	0	0	0												
Dec. 10	47	32																	0	0	0												
Dec. 11	47	26																	0	0	0												
Dec. 12	52	29																	0	0	0												
Dec. 13	54	30																	2	0	0												
Dec. 14	56	32																		0	0												

Dec. 15	56	32																		0	0												
Dec. 16	43	37																		0	0												
Dec. 17	43	36																		0	0												
Dec. 18	43	26																	1	0	0												
Dec. 19	50	24																		0	0												
Dec. 20	46	26																		0	0												
Dec. 21	50	31																		0	0												
																			60														
Dec. 22	41	20																		0	0												
Dec. 23	38	33																		0	0												
Dec. 24	36	34																		0	0												
Dec. 25	37	34																		0	0												
Dec. 26	34	31																		0	0												
Dec. 27	33	27																		0	0												
Dec. 28	39	27																		0	0												
Dec. 29	34	30																		0	0												
Dec. 30	34	30																		0	0												
Dec. 31	32	29																		0	0												
1914.																																	
Jan. 1	29	28																		0	0												
Jan. 2	35	30																		0	0												
Jan. 3	35	30																			0												
Jan. 4	35	31																			0												
Jan. 5	35	29																		29	0												
Jan. 6	33	30																			0												
Jan. 7	33	31																			0												
Jan. 8	45	31																			0												
Jan. 9	49	34																			0												
Jan. 10	38	27																			0												
Jan. 11	35	17																			0												
Jan. 12	35	10																			0												
Jan. 13	33	9																			0												
Jan. 14	43	22																			0												
Jan. 15	55	29																			0												
Jan. 16	55	35																			0												
Jan. 17	50	35																			0												
Jan. 18	40	30																			0												
Jan. 19	41	31																			[1] 0												

[1] Young still immature, so bring into greenhouse, since it is too cold for further development out of doors. Matured Jan. 21 and proved to be viviparous.

b=Date of birth.

In 1912, from young collected on clover in the field May 15, we obtained a maximum of 17 generations, and these field-collected specimens were doubtless of the second or third generation. From the same progenitor, following down the last-born generation series, a minimum of 8 generations was obtained, or an average of $12\frac{1}{2}$ generations for the year. (See Table III.) Mr. R. L. Webster (reported by Folsom [1909]) obtained 17 consecutive generations in one year (1905), beginning with the stem-mother hatching from the egg March 23.

TABLE III.—*First and last generation series from an individual Macrosiphum pisi collected in the field May 15, 1912, La Fayette, Ind.*

Date.	Temperature.[1]		First-born generation series.																	Last-born generation series.								
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.
1912.	°F.	°F.																										
May 15	65	46½	a																									
May 16	56	47½	0																									
May 17	67½	47	0																									
May 18	72	45½	0																									
May 19	73+	61	0																									
May 20	82½	.....	0																									
May 21	84	64	0																									
May 22	86	62	0																									
May 23	87½	67½	0																									
May 24	82	67	12																									
May 25	78½	60																										
May 26	83	56	10																									
May 27	89	66																										
May 28	81½	63	2																									
May 29	74	51	2	b																								
May 30	62	49																										
May 31	78	53	3	0																								
June 1	85	57½		0																								
June 2	87	61	9	0																								
June 3	77½	55		0																								
June 4	80	58		0																								
June 5	79	52	6	0																								
June 6	82	63		0																								
June 7	71	48		0																								
June 8	71	44	4	0																								
June 9	83	46		0																								
June 10	76½	53	4	0																								
June 11	81	55	5	7	b																							
June 12	85	58		4	0																							
June 13	80	56½	2	1	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	b							
June 14	78	61	0	5	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	0							
			59																									

June 15	82	66	...	10	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0						
June 16	82	67	...		0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0						
June 17	78	62	...	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0						
June 18	69½	57½	...	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0						
June 19	69	56	...		0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0						
June 20	73	51	...	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0						
June 21	77	58½	...	4	4	b	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0						
June 22	72	50	...	3	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0						
June 23	75	53	...	2	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0						
June 24	80	57	...	2	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4						
June 25	83	59	...	2	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5						
June 26	86	60	...	1	10	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2						
June 27	88	63	...	4	6	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6						
June 28	88	65½	...	2	9	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8						
June 29	88	66½	...	2	6	2	b	...	...	...	...	...	...	...	...	...	...	...	...	...	4						
June 30	87	66½	...	2	8	9	0	...	...	...	...	...	...	...	...	...	...	...	...	...	3						
July 1	87	60½	...	1	3	9	0	...	...	...	...	...	...	...	...	...	...	...	...	...	4						
July 2	85	68	...	0	8	9	0	...	...	...	...	...	...	...	...	...	...	...	...	...	6						
July 3	82	70	...	0	6	8	0	...	...	...	...	...	...	...	...	...	...	...	...	...	2						
July 4	81	70	...	1	2	8	0	...	...	...	...	...	...	...	...	...	...	...	...	...	2						
July 5	89	68	...	1	3	14	0	...	...	...	...	...	...	...	...	...	...	...	...	...	3						
July 6	89½	72	...	0	2	11	0	...	...	...	...	...	...	...	...	...	...	...	...	...	2						
				60																							
July 7	85	72	...	...	1	7	3	b	...	...	...	...	...	...	...	...	...	...	...	...	2						
July 8	84	69	...	...	0	2	7	0	...	...	...	...	...	...	...	...	...	...	...	...	0						
July 9	85	69	...	...	1	11	9	0	...	...	...	...	...	...	...	...	...	...	...	...	0						
July 10	89	70	...	...	0	2	6	0	...	...	...	...	...	...	...	...	...	...	...	...	1	b					
July 11	83	69	...	...	0	5	4	0	...	...	...	...	...	...	...	...	...	...	...	...	0	0					
July 12	84	67½	...	...	0	2	7	0	...	...	...	...	...	...	...	...	...	...	...	...	0	0					
						99															54						
July 13	84	73½	...	...	0	...	10	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0					
					92																						
July 14	88	70	...	...	...	...	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0					
July 15	86	75	...	...	...	...	7	11	b	...	...	...	...	...	...	...	...	...	...	...	...	0					
July 16	86	61½	...	...	...	...	7	7	0	...	...	...	...	...	...	...	...	...	...	...	...	0					
July 17	82	67	...	...	...	...	4	8	0	...	...	...	...	...	...	...	...	...	...	...	...	0					
July 18	82	60½	...	...	...	...	6	4	0	...	...	...	...	...	...	...	...	...	...	...	...	0					
July 19	80	57	...	...	...	...	4	6	0	...	...	...	...	...	...	...	...	...	...	...	...	0					
July 20	82	62	...	...	...	...	4	3	0	...	...	...	...	...	...	...	...	...	...	...	...	0					
July 21	85+	[2] 71	...	...	...	...	2	7	0	...	...	...	...	...	...	...	...	...	...	...	...	7					
July 22	78+	...	...	...	...	...	2	4	0	...	...	...	...	...	...	...	...	...	...	...	...	2					
								50																			
July 23	83½	65	...	...	...	...	0	...	3	b	...	...	...	...	...	...	...	...	...	...	...	5					
							84																				

[1] The maximum and minimum temperature records are taken for the period represented between the hour of last observation and the hour of noted observation.
[2] Lowest recorded temperature was 71° F. at 8 p. m. last night, at which hour the instrument ceased to record.
a = Date specimens were collected in the field and placed in breeding cage. b = Day of birth.

TABLE III.—*First and last generation series from an individual Macrosiphum pisi collected in the field May 15, 1912, La Fayette, Ind.*—Continued.

Date.	Temperature.		First-born generation series.																	Last-born generation series.								
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.
1912	°F.	°F.																										
July 24	91	76							8	0												7						
July 25	93	71							6	0												5						
									17																			
July 26	86½	61								0												1						
July 27	78	57								0												4						
July 28	81	63								0												4						
July 29	79½	66								0												4						
July 30	81	59								0												3						
July 31	81	61								0												2						
Aug. 1	71	52								0												3						
Aug. 2	74½	56								5	b											4						
Aug. 3	73	50								3	0											1						
Aug. 4	71	49								3	0											1						
Aug. 5	72	47								3	0											1						
Aug. 6	76	60½								7	0											1						
Aug. 7	81	65½								6	0											0						
Aug. 8	75	67½								6	0											3						
Aug. 9	81	69								5	0											2	b					
Aug. 10	73	61								0	0											0	0					
Aug. 11	76	63½								4	6	b										0	0					
Aug. 12	81	59								7	9	0										0	0					
Aug. 13	82	68								1	12	0										0	0					
Aug. 14	86	66								2	12	0										0	0					
																						63						
Aug. 15	88½	62								5	8	0											0					
Aug. 16	84	62								2	9	0											0					
Aug. 17	87	65								1	12	0											0					
Aug. 18	91½	70								3	8	2	b										8					
Aug. 19	91	70								3	4	8	0										6					
Aug. 20	99½	69								2	5	11	0										4					
Aug. 21	85	68								3	3	9	0										5					
											88																	

Aug. 22	85½	60								1		5	0										5				
Aug. 23	80½	56								0		3	0										3				
Aug. 24	85	58								0		0	0										2	b			
												38											33				
Aug. 25	87	68								0			0											0			
										72																	
Aug. 26	88	71											0											0			
Aug. 27	89	57											5	b										0			
Aug. 28	78	58											7	0										0			
Aug. 29	89	69											7	0										0			
Aug. 30	87	65											11	0										0			
Aug. 31	88	74											6	0										0			
Sept. 1	91	74½											8	0										5			
Sept. 2	89+	73½											3	0										4			
Sept. 3	91	69											4	0										3			
Sept. 4	95	70											3	(1)										2	b		
																								14			
Sept. 5	96	72											4		b										0		
Sept. 6	96½	70											4		0										0		
Sept. 7	88	70											4		0										0		
Sept. 8	88	66											3		0										0		
													69														
Sept. 9	93	[2] 69													0										0		
Sept. 10	95	66													1										0		
Sept. 11	95	69													(3)										2		
Sept. 12	84	51																							3		
Sept. 13	81	51														b									0		
Sept. 14	[4] 85	63														0									5	b	
																									10		
Sept. 15	85+															0										0	
Sept. 16	83	64														0										0	
Sept. 17	84	64														0										0	
Sept. 18	68	60														0										0	
Sept. 19	72	51														0										0	
Sept. 20	83	51														0										0	
Sept. 21	84½	62														0										0	
Sept. 22	[5] 72+	53														0										0	
Sept. 23	72+	44½														0										0	
Sept. 24	92½	54														2	b									2	
Sept. 25	80	61														5	0									8	
Sept. 26	80	39½														1	0									1	
Sept. 27	80	37														2	0									1	
Sept. 28	85	46														2	0									3	
Sept. 29	74	47½														3	0									2	b
																										17	

[1] No record kept for individual females. Four females produced 217 young. Last mothers died Oct. 12.
[2] Record ceased at 3.45 a. m.
[3] No record kept of individual. Three females produced 221 young. Last female died Oct. 19.
[4] No record from 10 a. m. Sept. 14 to 12 noon Sept. 15.
[5] No record from 8 a. m. Sept. 22 to 8.30 a. m. Sept. 23.
b=Day of birth.

TABLE III.—*First and last generation series from an individual Macrosiphum pisi collected in the field May 15, 1912, La Fayette, Ind.*—Continued.

Date.	Temperature.		First-born generation series.																	Last-born generation series.								
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.
1912.	°F.	°F.																										
Sept. 30	77	33													1	0										0	
Oct. 1	75	44													1	0										0	
Oct. 2	79½	39													0	0										0	
Oct. 3	80½	47½													3	0										0	
Oct. 4	72	44													5	0										0	
Oct. 5	79	46													3	0										0	
Oct. 6	84½	59													3	0										0	
Oct. 7	85½	52													2	0										0	
Oct. 8	59	41													3	0										0	
Oct. 9	68	45													4	0										0	
Oct. 10	76½	63													4	1	b									0	
Oct. 11	67	51													3	8										0	
Oct. 12	82	39													3	10	0									0	
															50												
Oct. 13	58½	35														2	0									0	
Oct. 14	64	38														1	0									5	
Oct. 15	63	38														2	0									3	
Oct. 16	66½	41														7	0									3	
Oct. 17	71	49															0									2	
Oct. 18	74	42														7	0									8	
Oct. 19	65½	37														3	0									1	
Oct. 20	59	41														1	0									2	
Oct. 21	66	52														5	0									4	
Oct. 22	78	41														7	0									5	
Oct. 23	57	32														1	0									0	
Oct. 24	51	32														1	0									1	
Oct. 25	58	34														2	0									2	
Oct. 26	65	38														3	0									2	
Oct. 27	66	45														1	0									1	
Oct. 28	72	45														3	0									1	
Oct. 29	73	50														6	0									9	
Oct. 30	74	36														3										0	
Oct. 31	58	38														1	8	b								4	
Nov. 1	45	36														1										1	

Nov. 2	36½	24															0	0	0								0	
Nov. 3	34	25															0	0	0								0	
Nov. 4	44	28															1	2	0								1	
Nov. 5	55	42															1	4	0								0	
Nov. 6	58	47															2	3	0								2	
Nov. 7	56	42															2	3	0								2	
Nov. 8	56	37															2	2	0								0	
Nov. 9	56	32															0	0	0								1	
Nov. 10	71	33															} 5	3	0								1	
Nov. 11	71½	51																6	0								4	
Nov. 12	75	55															5	4	0								3	
Nov. 13	63	47															1	0	0								1	
Nov. 14	42	34															0	3	0								0	
Nov. 15	39	27															1	2	0								2	
Nov. 16	46	28															1	1	0								1	
Nov. 17	47½	26															2	0	0								1	
Nov. 18	47	30															0	0	0								0	
Nov. 19	53	30															0	3	0								1	
Nov. 20	59	30															0	1	0								0	
Nov. 21	66	42															0	4	0								2	
Nov. 22	60	27															0	1	0								0	
Nov. 23	51	29															0	2	0								0	
Nov. 24	38	26															0	0	0								0	
Nov. 25	34	28															0	0	0								1	
Nov. 26	31	29															0	0	0								0	
Nov. 27	29	22															0	0	0								0	
Nov. 28	30½	19															0	0	0								0	
Nov. 29	34	20															0	0	0								} 3	b
Nov. 30	40	26															0	0	0									
Dec. 1	50	45															2	2	0								80	0
Dec. 2	59	38															0	} 3	0									0
Dec. 3	59	35															0		0									0
Dec. 4	41	38															} 1	} 1	3									0
Dec. 5	53	46																	3									0
Dec. 6																	0	0	0									0
Dec. 7																	0	0	0									0
Dec. 8																	0	0	0									0
Dec. 9																	0	0	0									0
Dec. 10																	0	0	0									0
Dec. 11																	0	0	0									0
Dec. 12																	0	0	0									0
Dec. 13																	0	0	0									0
Dec. 14																	0	0	0									(1)
Dec. 15																	0	0	0									
Dec. 16																	102	58	6									

1 Viviparous discontinued on account of cold.

b=Day of birth.

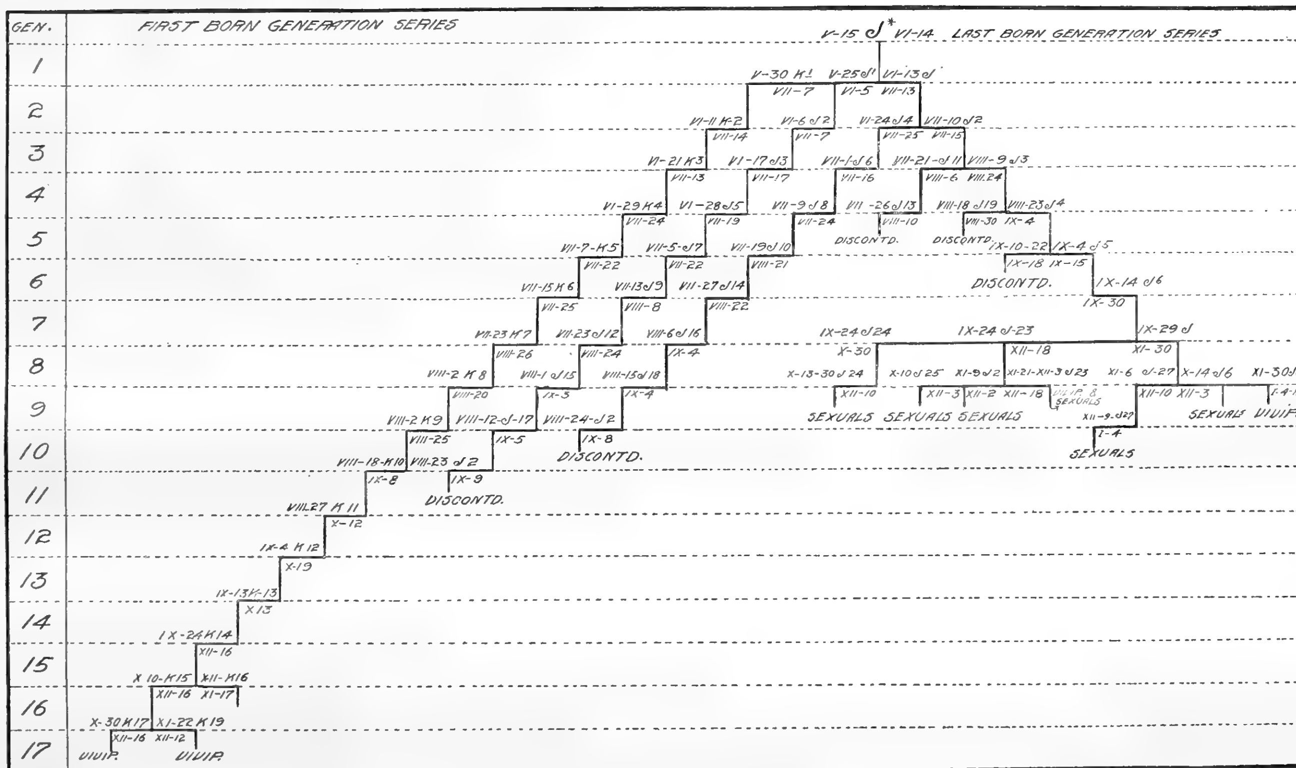

FIG. 11.—Graphic illustration of line of generations of *Macrosiphum pisi* in 1912 and individual cages, all the progeny of one mother. (Original.)

[* Immature individuals (probably second generation from egg) collected in the field May 15, 1912. Roman numerals indicate month, followed by day and cage number. Figures above line, date of birth and cage number; below line, date of death.]

Figure 11 shows graphically the lines of generations carried through in 1912 and the different individual experiments in each generation, including the cage number and dates of birth above the line and the date of death or termination of the experiment below the line, for each cage record. Figure 12 shows the length of each generation of the same series (1912).

Thus it will be noticed that the first generation in the series (probably the second generation from the egg) was the shortest, while the ninth generation was the longest, extending over a period of 156 days. Likewise it will be seen that on June 1 two generations coexisted; on July 1, four generations, from the second to the third; on August 1, seven generations, from the third to the ninth, inclusive, and on September 1, eight generations, from the fifth to the twelfth.

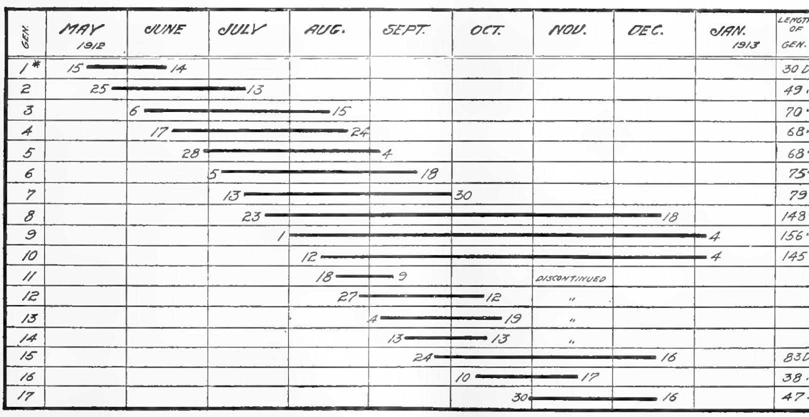

FIG. 12.—Periods and succession of generations in *Macrosiphum pisi*, La Fayette, Ind., 1912.

* This is the first generation found in the field and is probably about the third from the egg.

HATCHING OF THE EGG.

At La Fayette, Ind., the eggs of *M. pisi* hatch the latter part of March; in the cases recorded in 1913 they hatched March 31. Folsom (1909) records the hatching of eggs at Urbana, Ill., March 23, in 1905.

MOLTING.

According to our experiments this plant louse, like others of this family of insects, has five instars and never molts more than four times. In 1905 Mr. R. L. Webster, then an assistant of Dr. S. A. Forbes, State entomologist of Illinois, observed 10 individuals, all of which molted four times, although Mr. J. P. Gilbert, at the same laboratory, claims to have observed an individual molt five times (Folsom, 1909). Table IV gives our detailed records.

TABLE IV.—*Records of molts of Macrosiphum pisi. La Fayette, Ind., 1912.*

	Date of first molt.	Period between birth and first molt.	Date of second molt.	Period between first and second molts.	Date of third molt.	Period between second and third molts.
1911.		*Hours.*		*Hours.*		*Hours.*
11.00 a. m., Aug. 14.	7.30 p. m., Aug. 15.	32½	11.30 a. m., Aug 17.	40	Died	
1.00 p. m., Aug. 14.	5.30 a. m., Aug. 16.	40½	1.30 p. m., Aug. 17.	32	do	
11.00 a. m., Aug. 14.	8.00 a. m., Aug. 16.	45	Died			
3.30 p. m., Aug. 14.	5.30 a. m., Aug. 16.	38	7.00 p. m., Aug. 17.	37½	5.30 a. m., Aug. 19.	34½
3.00 p. m., Aug. 14.	5.30 a. m., Aug. 16.	38½	4.30 p. m., Aug. 17.	35	5.30 a. m., Aug. 19.	37
4.30 p. m., Aug. 14.	12.00 m., Aug. 16.	43½	5.30 p. m., Aug. 17.	29½	5.30 a. m., Aug. 19.	48
4.30 p. m., Aug. 14.	12.00 m., Aug. 16.	43½	9.00 a. m., Aug. 18.	45	5.30 a. m., Aug. 20.	44½
6.00 p. m., Aug. 14.	12.00 m., Aug. 16.	42	7.00 p. m., Aug. 17.	31	5.30 a. m., Aug. 19.	34½
9.00 a. m., Aug. 15.	5.15 a. m., Aug. 17.	44¼	5.30 a. m., Aug. 18.	24¼	11.30 a. m., Aug. 19	30
9.45 a. m., Aug. 15[1].	5.15 a. m., Aug. 17.	43½	6.30 a. m., Aug. 18.	25¼	2.30 p. m., Aug. 19.	32
10.00 a. m., Aug. 15.	5.15 a. m., Aug. 17.	43¼	5.30 a. m., Aug. 18.	24¼	2.30 p. m., Aug. 19.	33
10.15 a. m., Aug. 15.	6.00 a. m., Aug. 17.	43¾	9.00 a. m., Aug. 18.	27	3.30 p. m., Aug. 19.	30½
4.30 p. m., Aug. 18.	1.00 p. m., Aug. 20.	44½	11.45 a. m., Aug. 22.	46¾	3.30 p. m., Aug. 24.	51¾
4.30 p.m., Aug. 18.	5.30 a. m., Aug. 20.	37	4.45p. m., Aug. 22.	59¼	5.30 p. m., Aug. 25.	72¾
5.00 p. m., Aug. 18.	10.00 a. m., Aug. 20.	41	7.15 a. m., Aug. 23.	69¼	Died	
10.00 a. m., Aug. 19.	7.45 p. m., Aug. 20.	33¾	6.15 a. m., Aug. 22.	34½	5.15 a. m., Aug. 24.	47
10.00 a. m., Aug. 19.	5.30 a. m., Aug. 21.	43½	5.45 p. m., Aug. 22.	36½	7.30 a. m., Aug. 24.	37¾
1.00 p. m., Aug. 22.	9.45 a. m., Aug. 24.	44¾	5.30 a. m., Aug. 25.	19¾	Aug. 27	
1913.		*Days.*		*Days.*		*Days.*
Apr. 3 [2]	Apr. 4	1	Apr. 7	3	Apr. 9	2
Apr. 2 [2]	Apr. 4	2	Apr. 7	3		
Mar. 31 [3]	Apr. 5	5	Apr. 16	11	Apr. 19	3

	Date of fourth molt.	Period between third and fourth molts.	Date of first young.	Period between fourth molt and birth of first young.	Entire immature period (approximate).
1912.		*Hours.*		*Hours.*	*Days.*
11.00 a. m., Aug. 14					
1.00 p. m., Aug. 14					
11.00 a. m., Aug. 14					
3.30 p. m., Aug. 14	Removed for description.				
3.00 p. m., Aug. 14	5.30 a. m., Aug. 21	48	5.15 a. m., Aug. 22	23¾	7½
4.30 p. m., Aug. 14	5.00 p. m., Aug. 20	23½	5.15 a. m., Aug. 22	36¼	7½
4.30 p. m., Aug. 14	1.00 p. m., Aug. 22	31½	6.00 a. m., Aug. 23	17	7½
6.00 p. m., Aug. 14	7.45 p. m., Aug. 20	38¼	5.15 a. m., Aug. 22	33½	7½
9.00 a. m., Aug. 15	5.30 a. m., Aug. 21	42	1.00 p. m., Aug. 22	31½	7⅙
9.45 a. m., Aug. 15	8.00 a. m., Aug. 22	65½	6.00 p. m., Aug. 24	58	9⅓
10.00 a. m., Aug. 15	1.00 p. m., Aug. 21	46½	1.00 p. m., Aug. 23	48	8⅛
10.15 a. m., Aug. 15	1.45 p. m., Aug. 21	46¼	4.00 p. m., Aug. 23	50¼	8¼
4.30 p. m., Aug. 18	2.15 p. m., Aug. 26	46¾	Aug. 28		9+
4.30 p. m., Aug. 18	Died				
5.00 p. m., Aug. 18					
10.00 a. m., Aug. 19	Removed for description.				
10.00 a. m., Aug. 19	8.15 a. m., Aug. 26	48¾			8+
1.00 p. m., Aug. 22	Aug. 29		Aug. 30		8
1913.		*Days.*			
Apr. 3 [2]	Apr. 11	2	Apr. 14		11
Apr. 2 [2]	Apr. 14		Apr. 17		15
Mar. 31 [3]	Apr. 23	4	Apr. 24		24

[1] Winged female; all others wingless.
[2] Records by Gibson at Nashville, Tenn., in 1913.
[3] Hatched from egg.

It will be observed that only one record of a winged female was noted, and this individual required a noticeably longer time to reach maturity than did the wingless forms observed at the same time. This has been our observation time and again, although no definite records were kept.

AGE AT WHICH FEMALES BEGIN REPRODUCING.

In 1912 the age at which females began giving birth to young varied from 6 to 35 days, with an average of 10.3 days, from 38 records covering the months from May 15 to December. (Table V.)

TABLE V.—*Line of generations of Macrosiphum pisi from May 15, La Fayette, Ind., 1912.*

Cage number.	Generation.	Date of birth.	Date of first young.	Age at birth of first young.	Date of last young.	Reproductive period.	Life after last young.	Number of young.	Average young per day of productive period.	Largest number of young in one day.	Date of death or disappearance.	Total length of life.
First-born generation series:		1912.		Days.		Days.	Days.					Days.
J	[1] 1	May 15 [1]	May 24-25		June 13	20 or 21	1	59	2.8+ to 2.9+	5	June 14	
K1	2	May 30	June 11	12	July 5	25	2	60	2.4	5	July 7	38
K2	3	June 11	June 21	10	July 8	18	6	92	5.1+	10	July 14	33
K3	4	June 21	June 29	8	July 12	13	1	99	7.6+	14	July 13	21
K4	5	June 29	July 7	8	July 22	16	2	84	5.2+	10	July 21	25
K5	6	July 7	July 15	8	do	8		50	6.2+	11	July 22	15
K6	7	July 15	July 23	8	July 25	3		17	5.6+	8	July 25 [2]	10
K7	8	July 23	Aug. 2	10	Aug. 22	21	4	72	3.4+	7	Aug. 26	34
K8	9	Aug. 2	Aug. 11	9	Aug. 20	10		88	8.8	12	Aug. 20 [3]	18
K9	10	Aug. 11	Aug. 18	7	Aug. 22	5	3	38	7.6	11	Aug. 25 [3]	14
K10	11	Aug. 18	Aug. 27	9	Sept. 8	13		69	5.3+	9	Sept. 8	21
K11	12	Aug. 27	Sept. 4	8	([4])							
K12	13	Sept. 4	Sept. 10	6	([4])							
K13	14	Sept. 13	Sept. 24	11	Oct. 12	19	1	50	2.6+	5	Oct. 13 [3]	30
K14	15	Sept. 24	Oct. 10	16	Dec. 5	57	11	102	1.8−	10	Dec. 16	83
K15	16	Oct. 10 or 11	Oct. 30	19 or 20	do	37	11	58	1.6−	7	do	66 to 67
K17	17	Oct. 30 or 31	Dec. 4 [5]	35	do	2		6	3.0		Dec. 16-20 [6]	47 to 51
Last-born generation series:												
J1	2	June 13	June 24	11	July 10	17	3	54	3.2−	8	July 13	30
J2	3	July 10	July 21	11	Aug. 9	20	6	63	3.1+	7	Aug. 15	36
J3	4	Aug. 9	Aug. 18	9	Aug. 24	7		33	4.7+	8	Aug. 24	15
J4	5	Aug. 24	Sept. 1	8	Sept. 4	4		14	3.5	5	Sept. 4 [3]	11
J5	6	Sept. 4	Sept. 11	7	Sept. 14	4	1	10	2.5	5	Sept. 15 [3]	11
J6	7	Sept. 14	Sept. 24	10	Nov. 30	68		80	1.2−	9	Nov. 30	77
J7	8	Nov. 30	([7])									
Additional miscellaneous generation series:												
J1	2	May 24-25	June 6	12 or 13	June 28	23	7	41	1.8−	5	July 5	41 or 42
J2	3	June 6	June 17	11	July 4	18	3	60	3.8+	6	July 7	31
J3	4	June 17	June 28	11	July 14	17	3	106	6.2+	12	July 17	30
J4	3	June 24	July 1	7	July 18	18	7	119	6.6+	13	July 25	31
J5	5	June 28	July 5	7	July 19	15		94	6.3−	9	July 19	21
J6	4	July 1	July 9	8	July 15	7		41	5.9−	10	July 15	14
J7	6	July 5	July 13	8	July 21	9	1	37	4.1+	6	July 22 [3]	17
J9	7	July 13	July 23	10	Aug. 7	16	1	33	2.1−	4	Aug. 8 [3]	26
J10	6	July 19	July 27	8	Aug. 20	25	1	78	3.1+	7	Aug. 21	33
J11	4	July 21	July 26	5	Aug. 5	11	1	42	3.8+	7	Aug. 6	16
J12	8	July 23	Aug. 1	9	Aug. 23	23	1	72	3.1+	7	Aug. 24	32

J14	7	July 27	Aug. 6	10	Aug. 21	16	1	108	6.7+	12	Aug. 22	26
J15	9	Aug. 1	Aug. 12	11	Aug. 29	18	5	53	2.9+	6	Sept. 3	33
J16	8	Aug. 6	Aug. 15	9	Sept. 3	20	1	87	4.3+	10	Sept. 4	29
J18	9	Aug. 15	Aug. 23	8	...do	12	1	57	4.7+	11	...do	20
J23	8	Sept. 24	Oct. 10	16	Dec. 3	55	15	57	1.0+	9	Dec. 18	85

[1] Immature individuals collected in field; probably second or third generation from egg.
[2] Accidentally killed.
[3] Killed by fungus.
[4] By mistake progeny and life of single individual not kept.
[5] Placed in greenhouse Nov. 27 to hasten maturity. Transferred to outdoor shelter Dec. 4, after one mother had given birth to three young.
[6] Mother and young killed by cold.
[7] All viviparous and killed by cold.

The immature period varied from 7 to 56 days, between April, 1913, and January, 1914, with an average from 22 records of 15.3 days. (Table VI.)

TABLE VI.—*Line of generations of Macrosiphum pisi from stem-mother hatching from egg, La Fayette, Ind., Mar. 31, 1913.*

Cage number.	Generation.	Date of birth.	Date of first young.	Age at birth of first young.	Date of last young.	Reproduction period.	Life after last young.	Number of young.	Average young per day of productive period.	Largest number of young in one day.	Date of death or disappearance.	Total length of life.
First-born generation series:				*Days.*		*Days.*	*Days.*					*Days.*
Pi-1	1	Mar. 31	Apr. 24	24	May 22	29	8	88	3.0+	8	May 30	60
Pi-2	2	Apr. 24	May 7	13	June 2	27	13	124	4.6−	11	June 15	52
Pi-3	3	May 7	May 21	14	June 16	27	13	90	3.3+	7	June 29	53
Pi-4	4	May 21	June 2	12	June 23	22	6	111	5.0+	11	do	39
Pi-5	5	June 2	June 14	12	July 3	20	4	59	3.0−	5	July 7	35
Pi-6	6	June 14	June 22	8	July 5	14	2	68	4.8+	7	July 8	24
Pi-7	7	June 22	July 1	9	July 14	14	5	39	2.8−	6	July 19	27
Pi-8	8	July 1	July 18	17	Aug. 1	15	3	29	2.0−	4	Aug. 4	34
Pi-9	9	July 18	July 30	12	Aug. 14	16	0	38	2.3+	6	Aug. 14	27
Pi-10	10	July 30	Aug. 7	8	Aug. 8	2	1	5+	2.5	5	Aug. 9	10
Pi-11	11	Aug. 8	Aug. 16	8	Sept. 1	17	8	70	4.1+	8	Sept. 9	32
Pi-12	12	Aug. 16	Aug. 25	9	Sept. 12	19	16	57	3.0	7	Sept. 28	43
Pi-13	13	Aug. 25	Sept. 3	9	Sept. 20	18	11	73	4.0+	8	Oct. 1	37
Pi-14	14	Sept. 3	Sept. 10	7	Sept. 18	9	1	27	3.0	5	Sept. 19	16
Pi-15	15	Sept. 11	Sept. 23	12	Nov. 6	45	9	104	2.3+	7	Nov. 15	65
Pi-16	16	Sept. 23	Oct. 6	13	Nov. 21	47	14	96	2.0+	10	Dec. 5	73
Pi-17	17	Oct. 6	Oct. 16	10	Dec. 15–22	61–68	0	60	1.0−	6	Dec. 22	77
Pi-18	18	Oct. 16	Nov. 22	37	Dec. 8	17	25	29	1.7+	4	Jan. 2[1]	78
Pi-19a	19	Nov. 25–29	Jan. 24[1]	56–60	(2)							
Last-born generation series:												
PiPi-2	2	May 22	June 3	12	June 28	26	2	92	3.5+	7	June 30	39
PiPi-3	3	June 28	(3)									
PiPi-9	9	July 31	Aug. 9	9	Aug. 17	9	1	27	3.0	6	Aug. 18	18
PiPi-10	10	Aug. 17	Aug. 25	8	Sept. 15	22	4	75	3.4+	10	Sept. 19	33
PiPi-11	11	Sept. 15	Oct. 3	18	Oct. 17	15	28	23	1.5+	3	Nov. 14	60
PiPi-12	12	Oct. 14–16	(4)									

[1] 1914.
[2] Discontinued. Kept out of doors until Jan. 19, 1914, at which time temperature was too low to allow further development. Hence they were brought into a warm greenhouse, maturing as viviparous females Jan. 24.
[3] The actual last-born generation series broken by death of female in cage PiPi-3, so the last-born young of experiment Pi-8 was used to continue the last-born generation series, the cage being numbered PiPi-9.
[4] Matured Nov. 14 and proved to be winged males.

An average of all experiments for the two years, carried through out of doors and apparently under normal natural conditions, was 12.1+ days. As would be anticipated, and as is shown in Tables IV and V, the age at which females began reproducing was shortest during the warmer parts of the year and longest during the early spring and late fall months. In the case where immaturity lasted 56 days the aphis would doubtless have remained immature for a much longer time, possibly all winter, had it been left out of doors under natural conditions. (See footnote 1, Table VI.) From 16 individual experiments, between March 23 and September 21, Mr. R. L. Webster (Folsom, 1909) found that a female begins to reproduce 11 days after birth, on an average.

REPRODUCTIVE PERIOD.

The reproductive period—that is, the time or period during which the insect gave birth to young—varied from 2 to 68 days in 1912 and from 2 to 61 days in 1913, or an average for the two years (53 examples) of 22 days. In computing these averages some records, where the aphis was known to have died from other than natural causes, were not considered. Except in cases where death was due to other than natural causes, the female almost invariably lived several days after the birth of its last young, the length of time varying from 2 or 3 to 28 days.

LONGEVITY.

As is the rule with all of the Aphididæ, the pea aphis lives for a much longer time in the spring and fall, especially in the fall, than in the summer. In our records the total length of life—that is, from date of birth to date of death—of individuals varied from 10 to 85 days in 1912 and from 10 to 78 days in 1913, or an average of 39.1+ days from 51 records made during the two years. Tables IV and V may be referred to for the variation in lengths of life at the different times of the year. In Mr. Webster's experiments reported by Dr. Folsom (1909) the length of life of 16 individuals from as many consecutive generations varied from 13 to 50 days, with an average of 25.4 days.

FECUNDITY OF VIVIPAROUS FEMALES.

The aphis under discussion is one of the most prolific of all plant-lice. We find that a female may give birth to as many as 14 young in a period of 24 consecutive hours. The average number of young per female for all individuals where records were kept in 1912 and 1913 (59 examples) was 3.7+ per day, but this is the average for the entire reproductive period of each female, and as we learned, the birth rate greatly diminishes toward the latter days of its life, often not averaging one young a day. Taking this into consideration we find the average birth rate during the active life of the mother to be about 7 young per day, or even more. In our experiments individual females bore as many as 124 young, and Dr. J. W. Folsom (1909) reports a case where a single female produced 147 young. In Mr. R. L. Webster's experiment conducted at Urbana, Ill., in 1905 (Folsom, 1909) the average number of young borne by females of 16 consecutive generations was 46, while the average number of young produced by individual females in all our experiments conducted at La Fayette, Ind. (53 examples), excepting a few which were accidentally or prematurely killed, was 68.3+.

From these figures it is not difficult to see why this insect becomes so remarkably abundant, apparently within a few days, on its various hosts, and why it is able, collectively, to ravage and completely destroy crops almost before they become apparent to the casual observer.

SEXUAL FORMS.

Sexual forms may occur in the fall of the year, but there seems to be no uniformity in their production as is the case of certain other plant-lice. For instance, oviparous females may be produced by either wingless or winged females and the same female may produce both viviparous and sexual forms alternately; for example, in one of the experiment cages of 1912 a wingless female gave birth to her first young on October 10 and these proved to be oviparous females; later she gave birth to young which became viviparous females, and still later again bore oviparous females. A number of instances where females gave birth to viviparous and sexual forms alternately were observed in 1912 and 1913. Our earliest record of the birth of individuals of the sexual generation was October 10 in 1912 and October 14 in 1913. Dr. Folsom (1909) found the males in the field as early as October 10 in Illinois, and in one instance, in an experiment cage, an oviparous female was born as early as September 22. At Funkstown, Md., Mr. J. A. Hyslop observed the sexes of this species swarming on an alfalfa field November 12, 1912, the males and oviparous females predominating, although some viviparous females and young were observed. This observation was repeated at the same place by Mr. C. M. Packard October 28, 1913.

From these observations it is impossible to attribute the production of sexes to any particular cause. Certain aphids, notably *Aphis maidi-radicis, Sipha flava, Callipterus trifolii, Chaitophorus negundinis, Eulachnus rileyi*, etc., invariably produce the egg-laying forms toward winter in this latitude, and this may be attributed largely to the weather conditions; but in the case of *pisi*, both viviparous and oviparous forms are commonly borne of the same mother, and in the same line of generations, conducted under exactly identical conditions, reproduction may continue viviparously throughout the winter, while parts of one or more of these generations may become sexual forms. It is noted, however, that sexes are never produced at any time except in fall or early winter, and climatic conditions no doubt have some direct or indirect influence.

In our experiments oviparous females were produced much oftener than males, probably accountable from the fact that individual males may fertilize several females. The oviparous females are invariably wingless; but we have found both winged and wingless males, the latter in only a few instances in 1911. In the field Mr. Hyslop also observed the wingless male. In the case recorded by him a winged and wingless male were attempting to mate with the same female. To our knowledge these are the only two records of the occurrence of wingless males in America.

Mordwilko (10) has observed wingless males in Russia, and in his writings has described this form.

Copulation takes place soon after the individuals reach maturity, and egg laying commences shortly thereafter. Eggs are laid on the stems and leaves of red clover, according to our observations in Indiana; but Mr. Hyslop, in his observations with this species on alfalfa, mentioned above, found eggs only on the leaves of alfalfa and in no case on the stems, petioles, or axils. We have no records of the sexual forms being produced or eggs being laid on any plants other than red clover and alfalfa. However, Mordwilko (10) has observed the sexual forms on *Medicago falcata*, *Lathyrus latifolius*, and *L. angustifolius*, and Theobald (11) found them on the flat pea (*Lathyrus sylvestris*).

FECUNDITY OF OVIPAROUS FEMALES.

Actual counts of the number of eggs laid by individuals were not made, but dissections of 12 unfertilized females several weeks after maturity showed that they were capable of laying an average of 25 eggs. (See Table VII.) These counts indicate that the fecundity of oviparous females of *pisi* is twice that of the average aphidid.

TABLE VII.—*Number of eggs of Macrosiphum pisi.*

Date.	Number of eggs laid previous to date of dissection.	Number of apparently fully developed eggs found in body.	Number of immature eggs in body.	Total number of eggs exclusive of undeveloped ones.
Dec. 6, 1912	1 or 2	27	2+	28 or 29
Do	1 or 2	24	Several	25 or 26
Dec. 10, 1912	Avg. of 2 per ♀	18		20
Do	do	25		27
Do	do	25		27
Do	do	19		21
Do	do	18		20
Do	do	25		27
Do	do	21		23
Do	do	17		19
Jan. 4, 1913	2	26		28
Do	2	30		32
Average		23		24.8+

NATURAL CONTROL.

It is doubtful if any species of plant louse is more harassed by enemies than is the pea aphis. According to the observations of other writers, which we are able to corroborate, the common aphis fungus, *Empusa aphidis* (fig. 13), is the most important natural check on the increase of *Macrosiphum pisi*. This fungus thrives under moist conditions, especially when accompanied by warmth, and hence it usually makes its appearance after a few days of rainy weather and more often in summer—that is, during the warmer months. As might be inferred, this fungus is contagious and spreads with wonderful rapidity, frequently, as observed by us, so completely eradicating the insects that it was difficult and sometimes impossible to locate a single living plant louse. Diseased aphids first turn brownish and later become covered with the fungus threads. Thus weather conditions favorable for the growth of Empusa fungus are indirectly important. Furthermore, driving rains destroy great numbers of these plant lice, and very hot, dry weather seems to hinder excessive multiplication, so that weather conditions are a great factor in the natural control of this pest.

FIG. 13.—*Macrosiphum pisi* attacked by a fungus. Enlarged. (Original.)

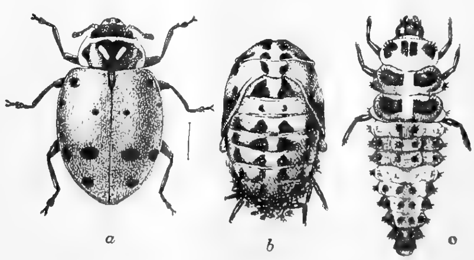

FIG. 14.—The convergent lady-beetle (*Hippodamia convergens*), an enemy of *Macrosiphum pisi*: *a*, Adult; *b*, pupa; *c*, larva. Enlarged. (From Chittenden.)

Next in importance in the natural control of this aphidid are the ladybirds, and of these no less than nine different kinds are known to prey upon it, namely, *Hippodamia convergens* Guer. (fig. 14), which is probably the most generally common and abundant of all the ladybirds; *H. glacialis* Fab., *H. 13-punctata* L., *H. parenthesis* Say, *Cycloneda munda* Say, *Coccinella 9-notata* Hbst., *Megilla fusci-*

labris Muls., *Adalia bipunctata* L., and *Chilocorus bivulnerus* Muls. Both larvæ and adults feed on the plant lice.

The larvæ of the syrphid flies (Syrphidæ), more generally known under the name of "sweat bees," are important enemies of the pea

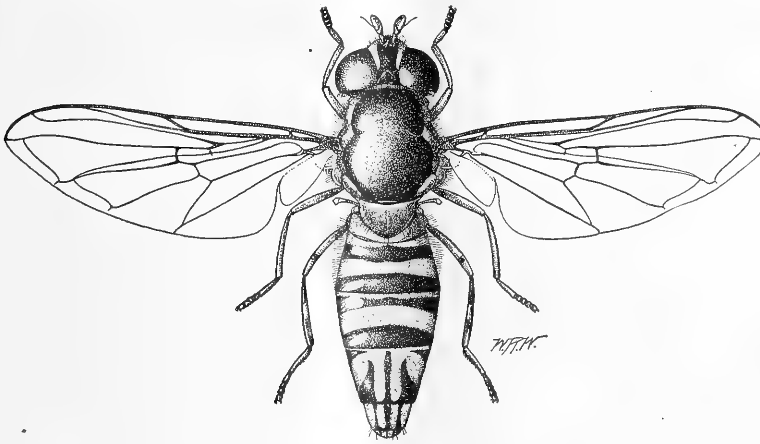

FIG. 15.—*Allograpta obliqua*, a syrphid fly the larva of which preys upon *Macrosiphum pisi*. (Original.)

aphis. The larvæ are sluglike and attack the aphis by piercing it and sucking the body juices. Each larva is capable of devouring many aphides in rapid succession. Johnson reports (1899) that one grower in Maryland, when separating peas, sieved out about 25 bushels of syrphid larvæ, mostly of the species *Allograpta obliqua* Say (figs. 15, 16), which is illustrative of the abundance of these larvæ at times. The adult flies are everywhere abundant in summer, and especially in the neighborhood of heavy aphis infestations. They hover in the air and at brief intervals fly rapidly, but only for short distances. Folsom (1909) enumerates eight species as attacking *Macrosiphum pisi*, namely, *Ocyptamus* (*Baccha*) *fuscipennis* Say, *Platychirus quadratus* Say, *Syrphus americanus* Wied., *S. ribesii* L., *Allograpta obliqua* Say, *Mesogramma marginatum* Say, *M. politum* Say, and *Sphaerophoria cylindrica* Say.

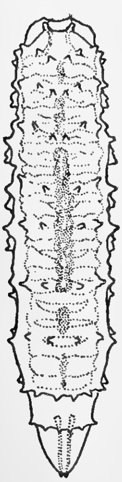

FIG. 16.—*Allograpta obliqua*: Larva. Much enlarged. (From Metcalf.)

Three species of lace-wing fly larvæ (Chrysopidæ), namely, *Chrysopa oculata* Say, *C. rufilabris* Burm., and *C. plorabunda* Fitch, feed on this plant louse. They are predacious in the larval stage, as is the case with the syrphids. The larvæ are provided with a pair of hollow bow-shaped mandibles or jaws, with which they grasp the aphis and through which its juices are sucked. The adults are pale green insects with relatively large lacelike wings, and from this character the common name is derived.

A small pinkish or orange larva (fig. 17) belonging to the family Cecidomyiidæ (*Aphidoletes* sp.)[1] is an active enemy of this plant louse, and although of small size, being only about one-eighth of an inch long, it has a remarkable capacity and is very prolific. It is the more effective because it does not attempt to consume all of the body fluids, as do the syrphids and chrysopids, but seems only to fed upon the juices of the captive plant louse until the latter is dead, soon after which the dead plant louse is discarded and another one attacked. Doubtless the predacious larva mentioned by Fletcher as *Diplosis* sp. was an Aphidoletes.

Other insects which are known to be predaceous on *Macrosiphum pisi* are several true bugs (*Podisus maculiventris* Say, *Euschistus variolarius* P. B., and *Triphleps insidiosus* Say), a tree cricket, *Oecanthus confluens* H. & H., and a beetle, *Podabrus rugulosus* Lec. Another beetle (*P. pruniosus* Lec.), closely related to the last named, has recently been reported by Mr. H. F. Wilson (1913) as feeding on "the vetch aphis (*Macrosiphum pisi* Kalt.?)." A mite (*Rhyncholophus parvus* Banks) is also known to attack this aphidid.

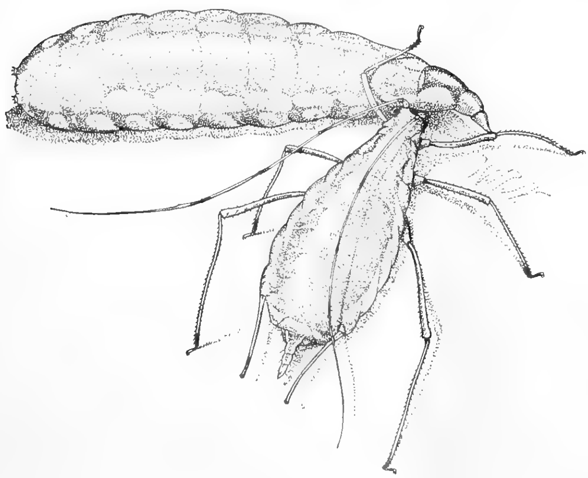

FIG. 17.—Larva of the syrphid fly *Allograpta obliqua*, which preys upon *Macrosiphum pisi*: Enlarged. (Original.)

The pea aphis is attacked by several internal parasites. Aphides thus attacked are inactive and finally die, becoming brown in color, and the adult parasite makes its exit from the dead aphis by cutting a circular hole in the dried skin. The species hitherto reported attacking this aphidid are *Aphidius fletcheri* Ashm. MS., *A. washingtonensis* Ashm., *Trioxys* (*Praon*) *cerasaphis* Fitch, and *Megorismus fletcheri* Cwfd. In the spring of 1915 Mr. W. B. Hall of this bureau reared *Aphidius rosae* Hal. and *Praon simulans* Prov. of this species collected at Wakeman, Ohio.

METHODS OF ARTIFICIAL CONTROL.

In the clover field the pea aphis is ordinarily held in check by its natural enemies. If it is apparent that this aphis is becoming un-

[1] Since the above was written Dr. E. P. Felt has determined Aphidoletes reared at La Fayette, Ind., in 1915 from larvæ attacking *Aphis gossypii* as *A. meridionalis* Felt. There is little question but that the species attacking *M. pisi* is identical.

duly abundant, the clover should be cut as soon thereafter as possible, since the cutting and drying of the clover will kill most of the insects. Clover which becomes coated with the honeydew of the aphides will not cure properly. Spring pasturing or early cutting back of the clover will check the multiplication of this plant louse.

A more brief general discussion of the pea aphis was published by Dr. F. H. Chittenden as Circular No. 43 of the Bureau of Entomology under the title "The Pea Aphis (*Macrosiphum pisi* Kalt.)," February 25, 1909, pages 1–10. This publication is now out of print, but can be consulted in most agricultural college libraries, as well as public libraries, and in private ones. A farmers' bulletin covering the same subject is in course of preparation.

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[1] Dates in italics refer to the more important references. Dates preceded by an asterisk indicate papers which have been inaccessible to the writer.

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1900. GIBSON, ARTHUR. Notes on insects of the year. Division No. 3, Toronto District. *In* 30th Ann. Rpt. Ent. Soc. Ontario f. 1899, p. 97–98, fig. 60–61.

Page 97. Reports injury to sweet and field peas in 1899 by *Nectarophora destructor*.

1900. HARRINGTON, W. HAGUE. Notes on insects of the year. Division I, Ottawa District. *In* 30th Ann. Rpt. Ent. Soc. Ontario f. 1899, p. 94–96, fig. 58–59.

Page 95. Injury to sweet peas in 1899 by *Nectarophora destructor*.

1900. HARVEY, F. L. Notes on insects and plants. Maine Agr. Expt. Sta., Bul. 61, p. 31–44, March.

Page 31. Reports much damage to garden and field peas in Maine in 1899 by *Nectarophora destructor*.

1900a. JOHNSON, W. G. The destructive green-pea louse. *In* Canad. Ent., v. 32, no. 2, p. 56–60, fig. 4–6, Feb.

Description of winged and wingless viviparous females as *Nectarophora destructor* n. sp. Distribution of the species and its natural enemies.

*1900b. JOHNSON, W. G. [*Nectarophora destructor* John.] *In* Canner and Dried Fruit Packer, Feb. 15, p. 42.

Injuries, description, habits, and remedies.

*1900c. JOHNSON, W. G. [*Nectarophora destructor* John.] Circulars Maryland State Hort. Dept. No. 7 (May 12), No. 11 (May 15), No. 13 (May 31), No. 19 (June 3). Figs.

Describes condition of pest in Maryland and methods being used against it.

*1900d. JOHNSON, W. G. The green-pea louse in Maryland. *In* Amer. Gard., v. 21, no. 284, p. 375, June 2.

1900e. JOHNSON, W. G. The destructive pea louse. *In* Rural New Yorker, v. 59, no. 2636, p. 525–526, fig. 178–179, August 4. Also: *In* Strawberry Cult. (The strawberry root louse), v. 7, no. 1, p. 7, August.

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Destructiveness of the pea aphis, with notes on life history and methods of control.

1900g. JOHNSON, W. G. Notes on insects of economic importance for 1900. U. S. Dept. Agr., Div. Ent., Bul. 26, n. s., p. 80–84.

Page 81. Injuries occasioned by the pea aphis.

1900. LUGGER, O. Bugs (Hemiptera) injurious to our cultivated plants. Univ. Minn. Agr. Exp. Sta., Ent. Div., Bul. 69, 259 p., 200 fig., 16 pl. Also: 6th Ann. Rpt. State Ent. Minn.

Page 201. Brief note on injuries in the East and in Wisconsin to peas by *Nectarophora destructor*.

1900a. PHILLIPS, J. L., and H. L. PRICE. The nature and use of certain insecticides. Va. Agr. Expt. Sta., Bul. 97 (n. s., v. 8, no. 2), p. 11–26, February, 1899.

Page 23. Reports on damage by *Nectarophora destructor* in 1898–1899 and on insecticide tests against this insect.

*1900b. PHILLIPS, J. L., and PRICE, H. L. The English pea louse. *In* South. Planter, v. 61, no. 4, April.

*1900a. SANDERSON, E. D. [*Nectarophora destructor* John.] The destructive pea louse. *In* Amer. Grocer, v. 63, no. 8, p. 13–14, 2 fig., February 21. Also: *In* Amer. Packer, Canner and Dried Fruit Packer, February 15, p. 38, figs.

Description, injuries, habits, enemies, and remedies.

*1900b. SANDERSON, E. D. The destructive pea louse. *In* The Canner and Dried Fruit Packer, March, 1900, figs.

1900c. [SANDERSON, E. D.] The destructive pea louse. Del. Col. Expt. Sta., Press Bul. 4, 1 p., May 15.

Injury to peas in 1899. Occurrence on clover, mode of spreading to peas, and means of control.

1900d. [SANDERSON, E. D.] The green-pea louse. Del. Col. Expt. Sta., Press Bul. 5, 1 p., June 1.

Injury to peas in 1900 in Delaware, susceptibility of different varieties, natural enemies, and control.

*1900e. SANDERSON, E. D. The destructive green pea louse. *In* Rural New Yorker, v. 59, no. 2629, p. 413–414, fig. 126–130, June 16.

*1900f. SANDERSON, E. D. Pea louse in Wisconsin. *In* Rural New Yorker, v. 59, no. 2644, p. 659, September 29.

1900g. SANDERSON, E. D. Notes from Delaware. U. S. Dept. Agr., Div. Ent., Bul. 26, n. s., p. 66–72.

Page 69. Record of the pea louse during 1900. Records numerous enemies of this aphidid and gives remedies.

1900h. SANDERSON, E. D. II. The destructive pea louse in Delaware. Del. Col. Agr. Expt. Sta., Bul. 49, p. 14–24, fig. 67, pl. 2–3.

Injury by *Nectarophora pisi*, its past history, brief description, food plants, spread of the pest, natural enemies, and means of control.

*1900. [SLINGERLAND, M. V.] Pea lice in New York State. *In* Rural New Yorker, v. 59, no. 2649, p. 737, November 3.

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Page 424. First observed injury to peas by *Nectarophora destructor* in 1898. Notices of individual reports of damage by this insect in 1898, and suggests preventive measures.

1900b. SMITH, J. B. Insects injurious to fruits. *In* Amer. Agr., v. 66, no. 25, p. 645, December 22.

*1900a. WEBSTER, F. M. [Quoted in Phila. (Pa.) Public Ledger.] April 4, 1904.

Occurrences of the pea louse at Toledo, Ohio.

1900b. WEBSTER, F. M. Insects of the year in Ohio. U. S. Dept. Agr., Div. Ent., Bul. 26, n. s., p. 84–90.

Page 88. Reports occurrence of *Nectarophora destructor* on Canada field peas, as well as red clover and garden peas, in various parts of Ohio. A fungus identified as ***Empusa aphidis*** destroyed myriads of the aphis.

1900. WEED, C. M. Insect record for 1899. N. H. Col. Agr. Expt. Sta., Bul. 72, p. 61–74, 11 fig.

Page 74. Reports damage to garden and sweet peas in various parts of New Hampshire, due to *Nectarophora destructor*.

1901. [Bureau of Entomology.] The principal injurious insects of the year 1900. U. S. Dept. Agr. Yearbook f. 1900, p. 725–729.

Page 726. Serious injury to peas by *Nectarophora destructor* along Atlantic coast and westward to Wisconsin. Remedies.

1901. Chapais, J. C. L'aphis des pois. *In* Nat. Canad., v. 28, no. 2, p. 17–20, Feb.

Reports serious injury to sweetpeas in August of 1900. Describes the insect (after Johnson). Observations of injury and remedies.

1901a. Chittenden, F. H. Remedies for insect pests in vegetable and flower gardens and conservatories. 4 p., 4 fig. Philadelphia.

Remedies for the pea louse.

1901b. Chittenden, F. H. The destructive green pea louse. U. S. Dept. Agr., Div. Ent., Circ. no. 43, 8 p., 3 fig., May 23.

A concise account of *Nectarophora destructor* Johns. as a pest of peas, under the following headings: Recent injury, descriptive, distribution, extent of injury and method of work, natural enemies, and method of control.

1901. Felt, E. P. Voluntary entomological services of New York State. *In* 16th Report of the State Entomologist on Injurious and Other Insects of the State of New York f. 1900 (Bul. N. Y. State Mus.), v. 7, no. 36, p. 1000–1026.

Pages 1003, 1017. Correspondent reports *Nectarophora pisi* not so injurious on Long Island as previous year. Also reported from Broome County.

1901. Fernald, C. H., and Fernald, H. T. Report of the entomologists. *In* 13th Ann. Rpt. Hatch Expt. Sta. Mass. Agr. Col. f. 1901, p. 84–88, Jan.

Page 87. Injury to peas by pea louse in 1900 but not so great as in 1899.

1901a. Fletcher, James. Injurious insects in Ontario during 1900. *In* 31st Ann. Rpt. Ent. Soc. Ontario f. 1900, p. 62–72, fig. 14–32.

Page 66. *Nectarophora destructor* not as abundant in 1900 as in 1899; notes reported injuries, remedies, and natural enemies.

1901b. Fletcher, James. Report of the entomologist and botanist. *In* Canada Expt. Farms Rpts. f. 1900, p. 195–249+ii, 18 fig.

Page 211. *Nectarophora destructor* was present in same districts as in the preceding year (1899) but in less injurious numbers. Notices of injuries and discussion of natural enemies, especially of the orange larva of a species of Diplosis.

1901c. Fletcher, James. Farm pests; fodder grasses. Evidence of Dr. James Fletcher, Entomologist and Botanist, before the Select Standing Committee on Agriculture and Colonization f. 1901, 25 p.

Page 20. Notice of injuries by the destructive pea aphis.

1901. Harvey, F. L. Notes on insects of the year 1899. *In* 16th Ann. Rpt. Maine Agr. Expt. Sta. f. 1900, p. 31–42.

Page 31. Reports *Nectarophora destructor* abundant and destructive to garden and field peas.

*1901a. Johnson, W. G. The destructive pea-louse. *In* Rural New-Yorker, v. 60, no. 2659, p. 17, fig. 7, Jan. 12.

*1901b. Johnson, W. G. Green pea industry threatened. *In* Amer. Agr., v. 67, no. 6, p. 202–203, 2 fig., Feb. 9.

1901. L., H. H. Pea louse in field peas. *In* Rural New-Yorker, v. 60, no. 2672, p. 267, April 13.

H. H. L. writes of field peas, grown with barley, being ruined in 1900 by the pea aphis. Suggests earlier planting.

1901a. Sanderson, E. D. Some plant lice affecting peas, clover, and lettuce. *In* Canad. Ent., v. 33, no. 2, p. 31–39, pl. 2, Feb.

Description of the winged and wingless viviparous female and winged male, together with comparisons with other species and supposed varieties. Concludes *pisi* of Europe and *destructor* of America identical.

1901b. SANDERSON, E. D. Danger from green pea-louse. *In* Rural New-Yorker, v. 60, no. 2692, p. 268, April 13.

Reply to correspondent who reports injury to fodder peas by the pea louse and of the successful use of whale-oil soap in combating it on garden peas.

1901c. SANDERSON, E. D. The destructive pea louse (*Nectarophora pisi* Kalt.). *In* 12th Ann. Rpt. Del. Col. Agr. Expt. Sta. f. year ending June 30, 1900, p. 169–186, fig. 8, pl. 2–3.

Account contains bibliography, description of the insect, past history, life history, injury, natural enemies, cause of outbreaks, and means of control.

*1901d. SANDERSON, E. D. Successful sprayer for the pea louse. *In* Rural New Yorker, v. 60, no. 2685, p. 481–482, fig. 204–205, July 13.

1901. SMITH, JOHN B. Report of the entomologist. *In* 21st Ann. Rpt. N. J. Agr. Expt. Sta. f. 1900, p. 479–572, 10 fig.

Page 505. General account of the life history of *Nectarophora destructor*. Review of known remedies and preventives.

1902. BRITTON, W. B. First report of the State entomologist. *In* Report of the Conn. Agr. Expt. Sta. f. 1901, pt. 3, p. 227–278+viii, 11 pl., 2 fig.

Pages 238, 276. The pea louse less abundant than in 1899 or 1900. Injuries and remedies.

1902. CHITTENDEN, F. H. The principal injurious insects in 1901. *In* U. S. Dept. Agr. Yearbook f. 1901, p. 674–679.

Page 675. The destructive pea louse not abundant except in a few isolated localities.

1902. FLETCHER, JAMES. Report of the entomologist and botanist. *In* Canada Expt. Farms Rpts. f. 1901, p. 197–262+ii, 19 fig., 1 pl.

Page 212. *Nectarophora destructor,* which occurred in Canada in injurious numbers in 1899 and 1900, almost entirely disappeared in 1901, one report only of injury being received.

*1902. JOHNSON, W. G. Protecting green pea crop from insects. *In* Amer. Agr., v. 69, no. 17, p. 584, April 26.

1902. PETTIT, RUFUS H. Some insects of the year 1901. Mich. State Agr. Col. Expt. Sta., Bul. 200, p. 179–212, 21 fig., May.

Page 198–200. Reference to injury in the United States and its occurrence in Michigan. Remedies.

1902. QUAINTANCE, A. L. Injurious insects of the year. *In* Rpt. Md. Hort. Soc. 4th Ann. Sess. held in Baltimore, Dec. 12 and 13, 1901, v. 4, p. 87–104, fig. 8–22.

Page 101. Less injury past year by pea louse. Injury most noticeable to late peas.

1902a. SANDERSON, E. D. Report of the entomologist. *In* 13th Ann. Rpt. Del. Agr. Expt. Sta. f. 1901, p. 127–199, fig. 13–33.

Page 168. Results of experiments in the control of *Nectarophora pisi* on peas.

1902b. SANDERSON, E. D. Insects injurious to staple crops. 295 p., 162 fig. New York.

Page 182. Brief account of *Nectarophora pisi*.

1902. SMITH, J. B. Report of the entomologist. *In* Ann. Rpt. N. J. Expt. Sta. f. 1901, p. 463–587, 36 fig.

Page 471. The pea louse was not so injurious as in 1900. Describes in detail a new sprayer adapted especially for this pest and efficacy of various remedies.

1902. WEBSTER, F. M., AND NEWELL, W. Insects of the year in Ohio. U. S. Dept. Agr., Div. Ent., Bul. 31, n. s., p. 84–90, Jan.

Page 87. Note on occurrence of the pea louse in Ohio.

1903. CHITTENDEN, F. H. The principal injurious insects in 1902. U. S. Dept. Agr. Yearbook f. 1902, p. 726–733.

Page 727. Reported damage by the pea louse negligible.

1903a. Felt, E. P. Importance of injurious insects introduced from abroad. *In* Report of the State entomologist on injurious and other insects of the State of New York for 1902 (N. Y. State Mus. Bul. 64), p. 116–126.

Page 122. Mentions *Nectarophora pisi* as an introduced species responsible for losses to pea growers in the Atlantic States.

*1903b. Felt, E. P. Importance of injurious insects introduced from abroad. *In* Proc. Soc. Prom. Agr. Sci., 24th Ann. Meet., p. 39–48.

1903. Fletcher, James. Report of the entomologist and botanist. Canada Expt. Farms Rpts. f. 1902, p. 169–201, 5 fig., 1 pl.

Page 179. Brief account of the destructive pea aphis. Worst attack the past season was on grass peas, hairy vetch, and field peas.

1903. Quaintance, A. L. Entomological notes from Maryland. U. S. Dept. Agr., Div. Ent., Bul. 40, p. 47–50, fig. 2.

Page 49. *Nectarophora pisi* was not injurious to peas past season (1902). Growers practice early planting to avoid injury.

1903. Smith, J. B. Report of the entomologist. N. J. Agr. Expt. Sta. Rpt. f. 1902, p. 425–508, 13 fig.

Page 425. Reports absence of pea louse in 1902, except on very late peas.

1904a. Britton, W. E. Third report of the State entomologist. Conn. Agr. Expt. Sta. Rpt. f. 1903, pt. 3, p. 199–286, fig. 27–42, 8 pl.

Page 212. *Nectarophora pisi* less abundant in 1903 than in 1902, though some injury to late peas.

1904b. Britton, W. E. Insect notes from Connecticut. U. S. Dept. Agr., Div. Ent., Bul. 46, p. 105–107.

Page 105. *Nectarophora pisi* less abundant than in 1902, but many late peas were injured.

*1904. Felt, E. P. Pea louse. *In* Country Gent., v. 69, no. 2673, p. 369, April 21.

Methods of controlling *Nectarophora pisi*.

1904. Fletcher, James. Insects injurious to Ontario crops in 1903. *In* 34th Ann. Rpt. Ent. Soc. Ontario f. 1903, p. 62–71, fig. 22–26.

Page 64. Reports injury to field and grass peas by the pea aphis.

1904. Pergande, Theo. On some of the aphides affecting grains and grasses of the United States. U. S. Dept. Agr., Div. Ent., Bul. 44, p. 5–23, 4 fig.

Page 21. The clover plant louse *Macrosiphum trifolii* is here described as new. Reports what he considers same species from wheat (*Triticum vulgare*), oats (*Avena sativa*), red clover (*Trifolium pratensis*), strawberry, sow-thistle (*Sonchus oleraceus*), and dandelion (*Taraxacum dens-leonis*).

1904–1906. Sanborn, C. E. Kansas Aphididae with catalogue of North American Aphididae and with host-plant and plant-host list. Pt. I–II. *In* Kans. Univ. Sci. Bul., v. 3, no. 1, p. 1–82, 22 pl., July, 1904, and v. 3, no. 8, p. 225–274, April, 1906.

Describes winged viviparous female of *Macrosiphum pisi* and reports taking it on rose. In the host plant catalogue the following hosts of *Macrosiphum pisi* are given: *Capsella bursa-pastoris*, cultivated beet, *Lathyrus odoratus*, cultivated pea, *Pisum sativum*, *Spiraea ulmariae*, *Trifolium repens*, *Urtica gracilis*, and *Urtica dioica*.

1904. Sanderson, E. D. Insects of 1903 in Texas. U. S. Dept. Agr., Div. Ent., Bul. 46, p. 92–96.

Page 96. Reports injury to garden peas in Texas by *Nectarophora pisi*.

1904. Smith, J. B. Report of the entomologist. *In* Rpt. Ent. Dept. N. J. Agr. Col. Expt. Sta. f. 1903, p. 557–659, 32 figs.

Page 563. Late peas were badly infested with the pea-louse.

1904. STENE, A. E. When to spray. Formulas and notes on spraying. R. I. Agr. Expt. Sta., Bul. 100, p. 121–148, 6 figs.

Page 129. Means against green pea louse.

1905. CHITTENDEN, F. H. The principal injurious insects of 1904. U. S. Dept. Agr. Yearbook f. 1904, p. 600–605.

Page 604. Only few complaints of injury by *Nectarophora destructor* reported from Colorado.

1905. FELT, E. P. 20th Report of the State Entomologist on injurious and other insects of the State of New York f. 1904. *In* N. Y. State Mus., Bul. 97, p. 359–597, 24 fig., 19 pl.

Pages 408, 416. Brief notes on life history, natural enemies, and remedies for *Nectarophora pisi.*

1905. FLETCHER, JAMES. Insects injurious to grain and fodder crops, root crops, and vegetables. Canada Cent. Expt. Farm, Bul. 52, 48 p., 8 pl. June.

Page 27. Brief account of injuries by *Nectarophora pisi*, and remedies.

1905. PETTIT, RUFUS H. Insects of the garden. Mich. State Agr. Col. Expt. Sta., Dept. Ent., Bul. 233, 77 p., 65 fig.

Page 40. Host plants and remedies for *Nectarophora pisi.*

1906. [BUREAU OF ENTOMOLOGY.] The principal injurious insects of 1905. *In* U. S. Dept. Agr. Yearbook f. 1905, p. 628–636.

Page 629. A few reports of injury by *Nectarophora destructor.*

1906. CONRADI, ALBERT F. Insects of the garden. Tex. Agr. Expt. Sta., Bul. 89, 52 p., 44 fig.

Page 4. *Nectarophora destructor* apparently widely distributed in Texas. Natural enemies and remedies.

1906. FLETCHER, JAMES. Report of the entomologist and botanist. *In* Canada Expt. Farms Rpts. f. 1905, p. 59–81.

Page 67. Refers to extensive destruction of pea crops in Canada in 1899.

1907. BETHUNE, C. J. S. Injurious insects of 1906 in Ontario. *In* 37th Ann. Rpt Ent. Soc. Ontario f. 1906, p. 45–56, fig. 3–17.

Page 49. Reports occurrence of plant lice on sweet peas.

1907. HITCHINGS, E. F. Second Ann. Rpt. of the State Entomologist of Maine f. 1906, 77 p., 19 fig., 1 pl.

Page 4. *Nectarophora pisi* reported from several localities in Maine.

1908. [BUREAU OF ENTOMOLOGY.] Principal injurious insects of the year 1907 U. S. Dept. Agr. Yearbook f. 1907, p. 541–552.

Page 544. *Macrosiphum pisi* reported rather more abundant than usual. Louisiana reported as a new habitat.

1908. CÆSAR, L. The annual meeting of the entomological society of Ontario. *In* Jour. Econ. Ent., v. 1, no. 6, p. 397–401, December.

Page 399. Serious damage to the late peas by the pea aphis was reported. Aphis fungus effective in some localities.

1908. GOSSARD, H. A. Spring practice in economic zoology. Ohio Agr. Expt. Sta., Bul. 198, p. 15–88+viii, 9 pl., November.

Page 86. Brief description of *Nectarophora destructor*, its injury to peas, and remedies.

1908. NEWELL, WILMON, AND ROSENFELD, ARTHUR H. A brief summary of the more important injurious insects of Louisiana. *In* Jour. Econ. Ent., v. 1, no. 2, p. 150–155, April.

Page 153. Reports injury to cowpeas by *Nectarophora pisi.*

1909. BARRE, H. W., AND CONRADI, A. F. Treatment of plant diseases and injurious insects in South Carolina. S. C. Agr. Expt. Sta., Bul. 141, 52 p., 1 fig.

Page 41. Means against green pea louse.

1909. [BUREAU OF ENTOMOLOGY.] The principal injurious insects of the year 1908. *In* U. S. Dept. Agr. Yearbook f. 1908, p. 567–580.

Page 571. *Macrosiphum pisi* was more injurious than for many seasons.

1909a. CHITTENDEN, F. H. The pea aphis. U. S. Dept. Agr., Bur. Ent., Circ. 43, ed. 2, 10 p., 7 fig., Feb. 25.

Revised account of an earlier edition. See 1901, Chittenden.

1909b. CHITTENDEN, F. H. Insects Injurious to Vegetables. 262 p., 163 fig., New York.

Page 114. Concise account of *Nectarophora pisi* as a pest to garden peas.

1909. CRAWFORD, J. C. Notes on some Chalcidoidea. *In* Canad. Ent., v. 41, no. 3, p. 98–99, March.

Describes "*Megorismus Fletcheri*" n. sp., which was reared from *Nectarophora pisi* at Ottawa, Canada.

1909. DAVIDSON, W. M. Notes on Aphididae collected in the vicinity of Stanford University. *In* Jour. Econ. Ent., v. 2, no. 4, p. 299–305, August.

Page 304. Reports *Macrosiphum pisi* from *Urtica holosericea* and Lathyrus. (The specimens from *Urtica* have been examined by the writer and prove not to be *pisi*. J. J. D.)

1909. FOLSOM, J. W. The insect pests of clover and alfalfa. Univ. Ill. Agr. Expt. Sta., Bul. 134, p. 113–197, 35 fig., 2 pl., April. Also *in* 25th Rpt. State Ent. Ill., p. 41–124, 35 fig., 2 pl.

Page 138. Important contribution, including distribution of the insect, its food plants, injury, descriptions, life history, habits, natural enemies, control, and bibliography of important literature.

1909. GIBSON, ARTHUR. Insects of the year 1908 at Ottawa. *In* 39th Ann. Rpt. Ent. Soc. Ontario f. 1908, p. 116–120, fig. 31–32.

Page 119. *Nectarophora pisi* reported abundant on field and sweet peas. Notes parasite reared.

1909. HUNTER, S. J. The green bug and its natural enemies. Univ. Kans. Bul., v. 9, no. 2, 221 p., 66 fig., 3 pl., folded tables 31–33.

Page 154. Unsuccessful experiments attempting to parasitize *Macrosiphum trifolii* with *Lysiphlebus tritici*. (Identification of the aphid doubtful. J. J. D.)

1909. JARVIS, C. D. Control of insects and of plant diseases. Storrs Conn. Agr. Expt. Sta., Bul. 56, p. 220–282, pl. 5–11, April.

Page 258. Remedies against pea louse.

1909. NEWELL, WILMON, AND ROSENFELD, ARTHUR H. Some common insects injurious to truck crops. State Crop Pest Comm. of La., Cir. 27, p. 93–131, 21 fig., July.

Page 108. Brief account of *Macrosiphum pisi*, including remedies and enemies.

1909. SWENK, MYRON H. The principal insects injurious to horticulture during 1908–1909. *In* 40th Ann. Rpt. Nebr. Hort. Soc. f. 1908 and 1909, p. 75–128, 16 pl.

Page 104. *Nectarophora destructor* reported injuring sweet peas.

1910. BETHUNE, C. J. S. Observations on Ontario insects in 1909. *In* 40th Ann. Rpt. Ent. Soc. Ontario f. 1909, p. 63–67.

Page 63. Garden peas attacked by plant lice.

1910. DAVIDSON, W. M. Further notes on the Aphididae collected in the vicinity of Stanford University. *In* Jour. Econ. Ent., v. 3, no. 4, p. 372–381, fig. 28–29, Aug.

Page 380. Records *pisi* from *Vicia* sp., cultivated bean, and *Urtica holosericea*. (See notes under 1909, Davidson.)

1910. ESSIG, E. O. Aphididae of Southern California. V. *In* Pomona Col. Jour. Ent., v. 2, no. 4, p. 335–338, fig. 124–125, Dec.

Page 336. Describes winged and wingless viviparous female *Nectarophora pisi*.

1910. FULLAWAY, DAVID T. Report of the entomologist. *In* Ann. Rpt. Hawaii Agr. Expt. Station f. 1909, p. 17–46, 8 fig.

Page 23. Describes *Macrosiphum trifolii* Perg. from specimens collected on *Sonchus oleraceus*. (The writer has examined these specimens and they prove not to be *Macrosiphum trifolii* Perg. J. J. D.)

1910. GIBSON, ARTHUR. Reports on insects of the year. *In* 40th Ann. Rpt. Ent. Soc. Ontario f. 1909, p. 9–14.

Page 14. Occurrences of *Nectarophora pisi* on sweet peas but less numerous than in 1908. Parasite mentioned.

1910. PETTIT, R. H. Insects of field crops. Mich, State Agr. Col. Expt. Sta., Bul. 258, p. 36–84, 51 fig., February.

Page 47. Briefly noted as a pest on peas.

1910. ROSENFELD, ARTHUR H. Insects notably injurious in Louisiana during 1908 and 1909. *In* Jour. Econ. Ent., v. 3, no. 2, p. 212–217, April.

Page 214. Considerable injury by *Nectarophora pisi* but less than in 1907.

1910. SMITH, J. B. Annual Report of the New Jersey State Museum Including a Report of the Insects of New Jersey, 1909. Trenton.

Page 118. [Nectarophora] Throughout the State south of Piedmont Plain and seasonably abundant and destructive.

1910. SAUNDERS, WILLIAM. Report of the Division of Entomology and Botany. *In* Canada Expt. Farms Rpts. f. 1909, p. 37–64.

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Page 168. Reported for clover in Nebraska.

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Page 26. *Nectarophora destructor* reported destroying field of peas. Also report of cattle poisoning from eating infested vines.

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Page 200. Brief account of *Macrosiphum pisi* as a pest on peas.

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Page 43. Brief account of *Macrosiphum pisi*, including remedies.

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Page 322. General account of the pea aphis (*Macrosiphum pisi*), its natural enemies and control.

1913. DAVIS, J. J. The Cyrus Thomas collection of Aphididae, and a tabulation of species mentioned and described in his publications. Ill. State Lab. Nat. Hist. Bul., v. 10, art. 2, p. 97–121, pl. 6–7.

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Page 235–237. Reports *Macrosiphum pisi* destructive to peas past season and experiments in methods of control.

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1915. Lochhead, W. Brief notes on some of the injurious insects of Quebec, 1914. *In* 45th Ann. Rpt. Ent. Soc. Ontario f. 1914, p. 59–61.

Page 60. Reports considerable injury to peas by *Macrosiphum pisi.*

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Page 71. Reports considerable injury by *Macrosiphum pisi.*

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 277

Contribution from the Office of Markets and Rural Organization, CHARLES J. BRAND, Chief

Washington, D. C. August 7, 1915

COTTON WAREHOUSE CONSTRUCTION.

By ROBERT L. NIXON,
Assistant in Cotton Marketing.

CONTENTS.

INTRODUCTION.

The purpose of this bulletin is to outline, in a general way, some of the essential features of a warehouse for the storage of cotton. It is a fact, not a theory, that loans on cotton in warehouses of "standard" construction can be obtained much more readily and at a lower rate of interest than on cotton stored in many of the other types of warehouses now widely used. The expense of storing cotton in an accepted type of warehouse, such as the standard, is much lower than in many of the structures now used. The present system of storing the bulk of the cotton crop in buildings which are not considered good risks by the insurance companies and the consequent high rate of insurance demanded on the cotton, together with the higher rate of interest on loans made on cotton stored in these warehouses, has resulted in a marked movement for the improvement of cotton-storage facilities. It may be used as a guide in deciding what type of warehouse to build and in making plans for the building; but neither the descriptions nor the illustrations should be used as specifications. An endeavor has been made to keep in mind the cost of construction, the arrangement necessary to minimize the cost of handling cotton, and those features which tend to reduce the insurance rate. The term "standard warehouse" does not refer to any Government standard, but to

NOTE.—This bulletin should be of special interest to warehousemen, cotton dealers, and those contemplating the construction of cotton warehouses, and of general interest to all farmers, bankers, and business men of the South.

the standards recognized by the fire insurance underwriters' associations. "Rates, Rules, and Forms" of the Southeastern Underwriters' Association are followed in discussing these standards and the insurance rates on cotton stored in such buildings. This association has jurisdiction in Virginia, North Carolina, South Carolina, Georgia, Florida, and Alabama. The rates and standards used in Mississippi are practically the same as those used by the Southeastern Association. The standards and the rates recognized in other cotton-producing States are very nearly the same as those outlined in this publication.

While this bulletin is intended primarily to treat of the construction of cotton warehouses, it seems advisable to discuss in a general way the importance of storage houses and the principles of storage. Thorough investigations show conclusively that the present storage houses are not rendering satisfactory service. An adequate system of warehouses would bring about important economic reforms in the handling and marketing of cotton. For this reason it seems wise to discuss these subjects before describing in detail the different types of warehouses.

IMPORTANCE OF STORAGE HOUSES.

It has long been realized that the inauguration of an adequate system of warehouses would aid greatly in marketing the cotton crop. This valuable staple, with an annual value of approximately $1,000,000,000, usually is harvested and marketed in 3 or 4 months. It requires 12 months for the mills of the world to consume this supply. It is quite evident that if this cotton continues to be forced on the market within a comparatively few months in each year, as at present, the price will be depressed unduly. This not only results in a material loss to the farmer, but the various branches of the trade are taxed in the effort to handle it in such a rush. When the output of any factory is in excess of the demand, the production is curtailed or the excess of manufactured articles is stored in order to conserve them properly until there is an increased demand. This is also true in the case of some agricultural products, but unfortunately the South is not prepared to conserve, even temporarily, the excess production of cotton in a proper and economical manner. It is also true that many of the farmers and dealers suffer a great loss because they do not understand the importance of protecting and conserving cotton while it is awaiting a fair market.

This condition becomes very serious during practically every cotton-picking season. The price is depressed during October, November, and December, when it is being sold by the farmer. The price then gradually increases, but this increase is of little benefit to the farmer, for he has disposed of his holdings. There seems to be only one way in which he can protect himself. He must prepare to hold his cotton until it is needed by the manufacturers and exporters. Then, and not until then, will he get a fair market price for the chief agricultural product of the South. In preparing to hold cotton it is very important that he should make some provision to protect it from damage by weather. It is also necessary to arrange his business affairs so that he can hold his cotton for a considerable length of time without becoming financially embarrassed.

An adequate storage system is essential for the proper handling and marketing of the cotton crop of the South, which, including the seed, is worth annually approximately $1,000,000,000. In many cases it is difficult for small merchants and growers to borrow money on cotton at 7, 8, or even 10 per cent. If it were stored in a standard warehouse belonging to a properly organized system it would unquestionably be possible for merchants to reduce this interest rate to 5 or 6 per cent and possibly to 4 or 4½ per cent. This would help greatly in financing and marketing this valuable staple.

In addition to cotton, various other articles could be stored to advantage if adequate facilities were offered. There is a great demand for storage space for fertilizers, farm implements, feedstuffs, and merchandise of various kinds. Storage facilities are needed also for various other agricultural products. There are at least $2,000,000,000 worth of farm products and merchandise that undoubtedly should be stored annually. It is remarkable that this opportunity for profitable investment of capital should be neglected. The inauguration of such a system of warehouses would give great impetus to the commercial development of this section. This subject is uppermost in the minds of the best business men, and all concur in the belief that properly equipped warehouses are a great necessity.

PRINCIPLES OF STORAGE.

Conservation is the central idea involved in warehousing. Storage is not entirely a modern business development. Some of the oldest business establishments of which we have any account were founded on the use of storage places. Ancient history gives some good illustrations of the value of conservation. The Phœnicians developed a wonderful commerce on the Mediterranean and became a rich and powerful people. Their facilities for handling and conserving wares made this great development possible. The Egyptians saved the surplus grain during years of abundant harvests, and when years of famine came they not only had plenty but sold the surplus they had saved to their neighbors at "corner" prices. Unfortunately, the American people have not been inclined to conserve their resources.

Nature has dealt so generously with them that they have not been compelled to realize the importance of saving. The South particularly has been inclined to disregard the future. The present crisis in the cotton market comes in a most unexpected manner and drives home the lesson of the importance of conservation. The grain growers of the Middle West have long realized the absolute necessity of a system of elevators for handling and storing their grain. Now the South realizes that a system of warehouses is essential for saving, handling, and marketing the cotton crop. Many are suffering because they have been too short-sighted to take the necessary precaution. Cotton lends itself more readily to storage than does any other valuable farm product. In view of this, it seems strange that storage has not been practiced. On the other hand, it is injured less by exposure than are most products. This partly accounts for the present attitude toward storage. Cotton does not demand storage; consequently it is grossly neglected.

FUNCTIONS OF A WAREHOUSE.

A warehouse has three legitimate and very important functions:

First, it offers temporary storage facilities when the person owning the product is not in a position to store it himself. In the cotton business, in normal years, this will cover the period from the time the cotton is ginned until it is sold by the farmer. It also provides the cotton dealer with a place in which to store his cotton from the time it is purchased until it is shipped.

Second, the warehouse should furnish the owner of the stored product a negotiable receipt. This receipt should show definitely what product is stored, the ownership, the amount of goods, the kind or grade, the condition, and the location of the warehouse. It should also show that the stored products are properly protected by insurance. The legal holder of such a receipt would be protected as fully as if he had the goods securely locked in his own vault.

Third, the warehouse provides a reservoir for surplus during years of overproduction or when market conditions are very unsatisfactory. When there is a surplus of any product there should be some way of saving it until there is a better demand for it.

In keeping qualities, cotton is superior to all other agricultural products. Properly stored it can be kept indefinitely without the slightest deterioration. It seems remarkable that so little advantage has been taken of this superior keeping quality. The fact that cotton can be left in the weather for several months doubtless accounts for some of the existing indifference to the subject. The South could save millions of dollars in normal years by protecting cotton from the weather. It is to be hoped that the lesson which is costing so much now will result in the saving of many times the present loss in future years. The inauguration of an ample and efficient system of warehouses would mark the beginning of a progressive revolution in the cotton markets.

Storage not only protects cotton from the weather, but from other forms of wear and tear. In many places where cotton is sold on the street, numerous large holes are cut in the wrapping for pulling samples. Frequently the owner loses several pounds in this unnecessary process, and the bale is left in a ragged and unsightly condition. It has been rendered less resistant to fire and exposure to weather by this damage. The samples are frequently thrown on the street and become a menace on account of increasing danger from fire. Besides this, they are unsightly and destructive of civic pride.

As yet the warehouse is the most practical and economical means of holding the cotton until it is needed. A recent investigation made by this office indicated that the total storage capacity of the warehouses now in use in the South is ample for protecting a maximum crop, but the same investigation showed clearly that only a very small percentage of these storage houses were properly located or so organized as to render efficient service.[1] It is also true that most of the present buildings are poorly constructed, thereby making it necessary to pay an excessive rate of insurance, and they are so arranged that the cost of handling cotton is unreasonably high. While it is true that in total capacity the present storage houses are sufficient, the results of the investigation emphasize the fact that in point of convenience and service rendered they are entirely inadequate.

The same investigation showed that cotton, when properly stored and insured with a reputable company, is considered by the most substantial bankers the very best collateral that can be offered. Numerous companies in the South have such arrangements with bankers as will enable the owners of cotton to store it with these companies and readily obtain loans on the best possible terms. Yet a large majority of the storage houses have very little business standing; consequently it frequently is difficult or almost impossible to borrow money on cotton stored with them. It is often true that these poorly organized companies are located in the cotton-producing communities. These are the kinds of warehouses with which many farmers have been compelled to deal, and frequently they are the only kinds of which they have any knowledge. For this reason their attitude toward storing is almost hostile. They know from experience that they have to pay entirely too much for the service rendered by the companies, and they naturally have concluded that it does not pay to store cotton.

[1] Nixon, Robert L. Cotton Warehouses: Storage facilities now Available in the South. U. S. Department of Agriculture, Bulletin 216, 1915.

Notwithstanding all of the objectionable features of the storage business as now conducted, the farmer frequently considers it necessary or to his advantage to hold his cotton. The past year has been most strenuous for the cotton farmer; one of the largest crops ever produced in the United States, the growth of 1914, has left his hands. However, the world's visible supply, at the opening of the new cotton year, August 1, was in round figures about 1¾ million bales larger than a year earlier. That means a large proportion of the world's cotton crop of 1914 growth was carried over and added to this season's crop. However, the exports of cotton from this country during the cotton year closed August 1, 1915, were very close to those of the year ended August 1, 1914. This year's crop, at the time of this bulletin's going to press, is still in the making. But when it is considered that in normal years there is a loss of from $30,000,000 to $75,000,000 from what is generally, although incorrectly, called "country damage," it will be seen that there is ample need of an adequate warehousing system, regardless of whether the crop is larger or smaller than normal.

In connection with the value of a negotiable warehouse receipt, it should be said that proper State laws covering the issuance of the receipts are necessary. In order to be of greatest value the warehouse receipts should show beyond question the ownership of the product stored, and this accuracy can not be accomplished unless the States in which the warehouse companies operate have laws that properly guard the issuance of receipts. If the laws of the State in which the warehouse is located are such as to throw any cloud upon the title of the goods covered by the receipt, the receipt immediately becomes almost worthless as collateral and defeats any effort to borrow money at cheap rates from outside sources. In addition to enacting such laws as will guarantee effectively the integrity of warehouse receipts, it seems advisable for all States to adopt a law of uniform warehouse receipts. This law is now in effect in many of the States, and has been approved by the American Warehousemen's Association, the American Bankers' Association, and the American Bar Association as being the best form in which laws can be made to protect both the owner of the goods and the lender of money against the receipts covering such goods.

The investigations previously referred to showed that there has been great loss in the construction of the present warehouses. The data gathered seemed to prove that the average insurance rate on cotton in the buildings now in use is not less than $2 per annum on $100. It is also true that if the money that has been spent on these buildings had been expended economically and intelligently in the construction of standard warehouses, properly protected with automatic sprinkler equipment, the rate of insurance could be reduced to 25 cents per $100. This would represent an enormous annual saving. Many of the inferior buildings now in use should be discarded entirely, and new warehouses, located with reference to the probable demands for storage, should be built. It would be possible also to remodel many of the poorly constructed buildings which are well located, so as to increase their efficiency and effect a great saving in the cost of insurance.

EXPLANATION OF THE TERM "STANDARD" AS APPLIED TO COTTON WAREHOUSES.

An endeavor has been made to give reliable information in regard to types of warehouses and insurance rates. A person who is preparing to build will get better results, especially in insurance rates, by following the suggestions given here, but, as previously stated, the types of warehouses described are not to be regarded as "Government standards" in any sense. They are the standards recommended by the fire insurance underwriters' associations. Buildings erected in accordance with these standards command a much lower rate of insurance than those that do not conform to them. While endeavors have been made in this bulletin to give definite information about insurance rates, no responsibility is assumed by the writer as to the correctness of the rates quoted, or the accuracy of the descriptions of the different types of storage houses. Anyone planning to build should have specifications drawn by an architect (many carpenters can make satisfactory plans) and submitted for approval to the underwriters having jurisdiction. This plan usually will save the prospective builder a great deal of money, especially in insurance rates.

TYPES OF STANDARD WAREHOUSES.

STANDARD I.—CLOSED COTTON WAREHOUSE (DETACHED), COMPARTMENTS LIMITED TO 600 BALES' CAPACITY.

The standard for the closed warehouse of two or more compartments requires that it should not be exposed by other buildings within 100 feet, and that no compartment should have a capacity exceeding 600 bales. To be most effective, this warehouse should be a low, one-story structure. In figure 1 is shown the proper size and arrangement of the compartments composing such a warehouse. The bales of cotton should be stored on end, only one bale deep, and at least one passageway with a minimum width of 4 feet should extend through the compartment the longest way, leading to a door at each end. (See fig. 12.) Such a passageway facilitates handling cotton during the transaction of ordinary business and is a necessity in properly controlling a fire.

Walls.—A blank wall of brick not less than 17 inches in thickness [1] should separate each compartment. This wall should be parapeted above the roof at least 3 feet, and the parapets should be capped with durable coping. The wall and parapet should extend 3 feet beyond the frame end walls. Division walls forming a T instead of extending beyond the frame end walls would be a desirable improvement. Outside end walls should be constructed of clapboards (weather boards) securely nailed to posts and studding, which render the wall

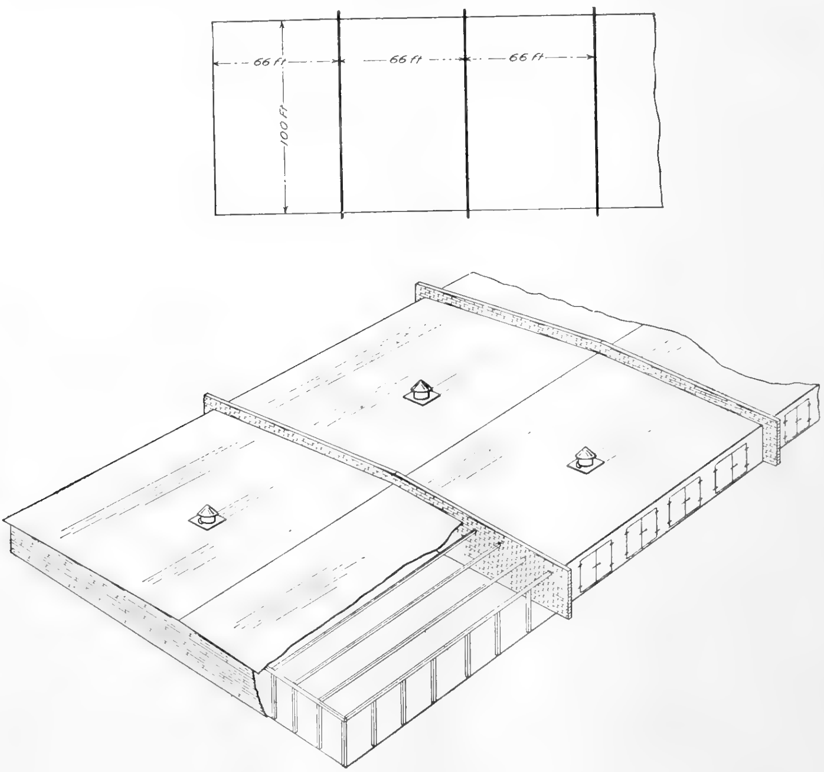


FIG. 1.—Closed cotton warehouse, compartments limited to 600 bales capacity—detached.

spark proof and weatherproof. All woodwork exposed to the weather should be painted or whitewashed. When the end of the warehouse, which is formed by the outer side walls of the end compartments, is exposed, this wall should be of brick at least 13 inches thick and coped in the same manner as the division walls.

Floors.—Floors should be preferably of concrete, but may be of earth, brick, or some other incombustible material. (See discussion of floors on p. 32.) When the floor is elevated to the height of the car floor, with frame platforms extending across the ends of the compartments, the division walls should be built from the ground to the

[1] The thickness of walls referred to in all of the standards are for one-story buildings. For thickness required in buildings of greater height, see table on p. 32.

height of the platform and should extend through these platforms so as to cut them off into divisions corresponding to the compartments in the warehouse.

Roof.—The roof should be of light mill construction, with a minimum thickness of 2 inches splined or tongued and grooved, supported by timbers single thick (not less than 6 by 8 inches) and spaced 8 or 10 feet apart. One end of the timber should rest on brick ledges or division walls, corbeled out to form suitable supports. The posts should be not less than 8 by 8 inches, and all corners of timbers and posts should be chamfered. Monitors, skylights, and roof lanterns should not be allowed unless they are made of wired glass, properly set in metal frames. The roof should be covered with gravel or approved composition. A roof of ordinary open-joist construction covered with gravel or approved composition will be classed as standard, but if automatic sprinklers are to be installed, it will be necessary to have from 25 to 50 per cent more heads than are necessary in the case of a roof of mill construction.

Samples.—All standards should require that the cotton be graded, and all books showing the number of bales, weights, and marks should be kept in some locality a sufficient distance from the warehouse or in a separate fireproof compartment or vault, so as not to be damaged by fire. Such books and samples also should be kept in a fireproof compartment or vault.

Doors.—The ends of the compartment should have as many doors as possible, and in no case should the doors be more than 3 feet apart. They should be heavy and securely made, hung on strong hinges, and should open outward so as to facilitate the rapid movement of cotton in case of fire.

Ventilators.—The top of each compartment should be provided with one or more approved metal ventilators.

Fire protection.—A connection of not less than a 6-inch pipe with a city water main of equal or larger diameter is necessary. One standard hydrant for each three compartments should be placed opposite the front or rear ends. Not less than 100 feet of approved 2½-inch cotton, rubber-lined hose should be kept attached to each hydrant. Six casks and 12 pails filled with water must be provided for each 600 bales storage capacity.

SCHEDULE FOR RATING.

	City.[1]		Town.[1]	
	First class.	Second class.	Third class.	Fourth class.
Basis rate	$1.15	$1.25	$1.35	$1.50

[1] For classification of cities and towns, see p. 28.

This schedule of rates is subject to material reduction if the property is protected with standard automatic sprinkler equipment.

Add for deficiencies as follows:

1. Floors, not standard	$0.10
2. Variation from requirements as to number of doors, 5 cents for each door; total charge not to exceed	.15
3. Skylights, not standard	.10
4. Private fire protection, none, or not standard	.25
5. Fire pails and casks of water, none, or insufficient supply (6 casks and 12 pails to compartment)	.50
6. Storage of lime or oils or use of any portion of building for stabling purposes or for "camping"	.50
7. Accumulation of loose cotton on floor or in other than closed bins	1.00

Make deduction as follows:

Chemical fire engine (40-gallon, approved, on wheels, having sufficient hose attached to reach any part of plant or premises): A deduction of 5 per cent of final rate will be granted, except on risks that have full credit in rate for standard private fire protection; said deduction not to be less than 5 cents and not to exceed 30 cents.

ADAPTATION OF STANDARD I.

The standard warehouse with compartments limited to 600 bales capacity, as just described, is used largely by the cotton mills. The Office of Markets and Rural Organization has just published the results of an extensive survey in Georgia and North Carolina, which showed that a large number of mills have constructed warehouses of this type and equipped them with automatic sprinklers at a cost of less than $3 per bale capacity. The same investigation showed that the rate of insurance on cotton stored in such buildings, when fully equipped with automatic sprinklers and fire hose, is frequently less than 12½ cents on $100 of value.[1] While buildings of this character are used largely by the mills and designed primarily to meet their particular needs, it would be well for any person preparing to erect either a public or private warehouse to consider very carefully the merits of this type.

No attempt is made to convey the impression that every public warehouse of this type would be able to insure cotton at 12½ cents per $100. The underwriters' association does not publish any schedule for rating such sprinkled risks, but it seems to be safe to state that cotton stored in such a building and in a first-class city could be insured for 25 cents, or for 30 cents in a second-class city, 35 cents in a third-class town, and 40 cents in a fourth-class town. The cotton mills are able to get a much lower rate on their own warehouses in the mill yards because the mill mutual insurance companies make special rates on this particular kind of risk. A certain mutual insurance company also writes insurance on such private warehouses at a much lower rate than the so-called "old-

[1] Nixon, Robert L. Cotton Warehouses: Storage Facilities now Available in the South. U. S. Department of Agriculture, Bulletin No. 216, 1915.

line" companies. When a person is building a warehouse for private use in which his own cotton will be stored largely, he can often cut the public rate materially by having his storage house conform very closely to the standard as outlined. It will be seen that this particular type of warehouse will save much in insurance rates, especially when it is used for private purposes, and it has many advantages as a public storage house.

STANDARD II.—COTTON WAREHOUSE OF FRAME CONSTRUCTION (DETACHED).

In capacity, arrangement of doors, and general construction, Standard II is exactly the same as Standard I. However, in Standard II each compartment is a separate warehouse. These houses

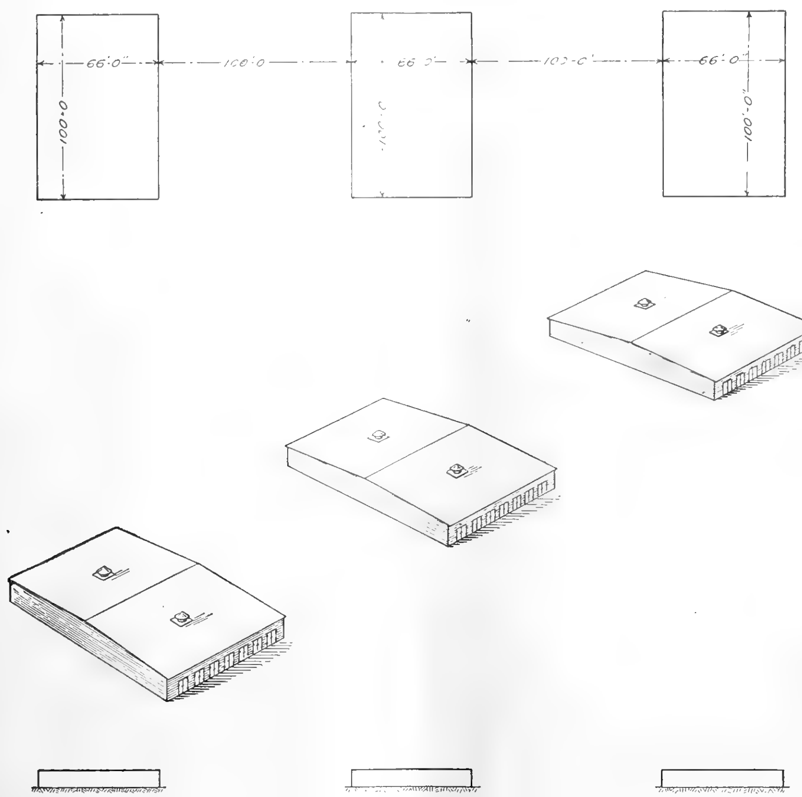


FIG. 2.—Cotton warehouse of frame construction—detached.

must be placed at least 100 feet apart, and must be no nearer other buildings than that distance. This avoids the use of brick division walls. The ends, roof, floor, etc., are exactly the same as in Standard I, but the side walls are of wood. In this type, two board walls and a space of 100 feet are substituted for the standard fire wall separating the compartments in Standard I. The diagram (fig. 2) shows three of these compartments properly arranged. The requirements for private fire protection are the same as in Standard I.

SCHEDULE FOR RATING.

	City.		Town.	
	First class.	Second class.	Third class.	Fourth class.
Basis rate	$2.15	$2.25	$2.35	$2.50

Charges for deficiencies for this type are the same as for Standard I. Deductions as outlined under Standard I will also apply to Standard II.

ADAPTATION OF STANDARD II.

The standard warehouse of frame construction limited to 600 bales storage capacity is not to be recommended for general use. Where real estate is so cheap that it can hardly be considered as an item in the cost of a storage plant, and where cotton is to be handled in small lots of 500 or 600 bales, it might be to advantage to construct such houses, but in most cases the additional land required would cost much more than it would to erect a warehouse with several compartments separated by standard fire walls. Where large quantities of cotton are handled, the cost of trucking would be greatly increased by having each compartment separated from the others by a space of 100 feet. It is also well to take into consideration the fact that insurance on cotton in such buildings is much higher than it is in the building described under Standard I.

STANDARD III.—CLOSED COTTON WAREHOUSE (OR COMPRESS), COMPARTMENTS LIMITED TO 1,000 BALES' CAPACITY.

Construction of building.—The outside walls of a one-story building conforming to this standard should be of brick not less than 13 inches in thickness, with or without standard parapets. (See p. 32 for requirements of thickness of walls for buildings more than one story high.) The roof should be of slate, metal, or approved composition. The storage capacity of no compartment should exceed 1,000 bales, which requires about 72,000 cubic feet. If divided into compartments, the division walls should be at least 17 inches in thickness for a one-story building and should extend at least 2 feet above the roof. All joists should rest on ledges, metal hangers, or metal wall plates. Each compartment should have one or more standard fireproof doors, not more than 40 feet apart, opening outward, in each outside wall, whether at end or side of compartment. The floors should be of earth, shell, cement, or some other noncombustible material. Monitors, skylights, and roof lanterns, or texas, are not allowed unless they are made of wired glass properly set in metal frames. The top of each compartment should be provided with one or more metal ventilators. The compress tower should be of metal or some other noncombustible material.

Samples.—All cotton stored in a warehouse of this standard should be graded, and the samples, together with books and other records, should be properly stored at a safe distance from the storage compartments.

Fire protection.—Six casks and 12 pails filled with water should be provided for each 1,000 bales storage capacity. Not less than a 6-inch connection with a city main of equal diameter or larger is required. One standard hydrant for each three compartments or fraction thereof is necessary. The hydrants should be placed opposite the front and rear ends of the compartments. Not less

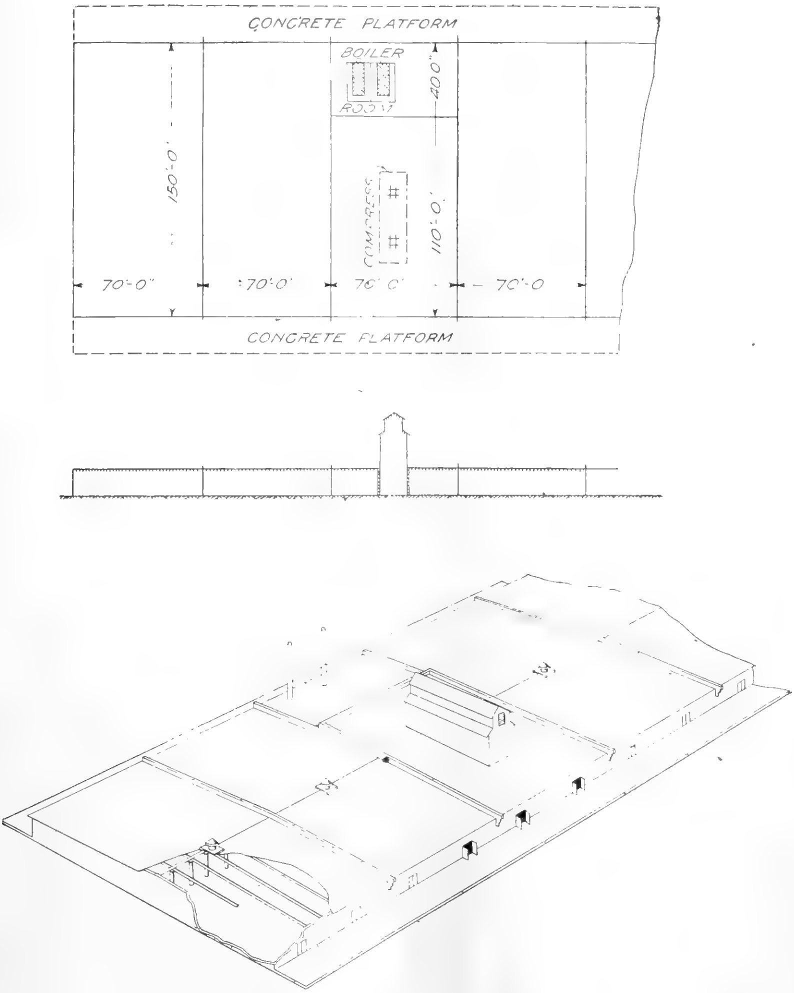


FIG. 3.—Closed cotton warehouse (or compress), compartments limited to 1,000 bales capacity.

than 100 feet of approved cotton, rubber-lined hose should be attached to each hydrant, and a standard hose house fully equipped should be erected over each hydrant.

An approved and convenient arrangement for a warehouse of this type is shown in figure 3. This diagram shows a warehouse of one compress compartment, as indicated. A warehouse conforming to Standard III may be constructed without a compress.

SCHEDULE FOR RATING.

	City.		Town.	
	First class.	Second class.	Third class.	Fourth class.
1. Standard mill construction with fire walls and approved roof	$1.15	$1.25	$1.35	$1.50
2. Same as No. 1, with shingle or unapproved roof	1.40	1.50	1.60	1.75
3. Same as No. 1, except that walls are of concrete blocks or of corrugated iron	1.65	1.75	1.85	2.00
4. Frame building with approved floor	1.90	2.00	2.10	2.25
5. Frame building with shingle or unapproved roof	2.15	2.25	2.35	2.50

This schedule of rates is subject to material reduction if the property is protected with standard automatic sprinkler equipment

Add for deficiencies as follows:

1. Height:
   - For 2-story building $0.10
   - For 3-story building .... .25
   - For 4-story building .... .50
   - For 5-story building .... .75
2. Variation from standard as to joist supports .... .10
3. Outside brick walls, not standard .... .25
4. One outside frame or iron-clad wall .... .50
5. Division walls, not standard .... .25
6. Excess in capacity of compartments or warehouses:
   - Over 1,000 bales and not exceeding 1,500 bales .... .25
   - Over 1,500 bales and not exceeding 2,000 bales .... .50
   - Over 2,000 bales and not exceeding 2,500 bales .... .75
   - For each 1,000 bales additional .... .25
7. Variation from requirements as to number of doors .... $0.05 to .15
8. Skylights, monitors, or roof lanterns, not standard .... .10
9. Private fire protection, none, or not standard .... .25
10. Fire pails and casks of water, insufficient supply (i. e., less than 6 barrels and 12 fire pails for each 1,000 bales capacity) .... .50
11. Storage of lime or oils, or use of any portion of building for stabling purposes or for "camping" .... .50
12. Accumulation of loose cotton on floors or in other than closed bins 1.00

ADAPTATION OF STANDARD III.

This standard is used largely for public warehouses, especially in the small towns of the Southeast. It will be seen in the "Schedule for rating" that it may be of standard brick construction with approved roof, or, with unapproved roof, built of concrete blocks, corrugated iron, or of frame construction. When a warehouse is exposed within a hundred feet it would seem to be advisable to have it conform to Standard III, but outside walls of corrugated iron or wood are not to be recommended in such cases. As a rule, the more costly building is to be recommended. Such a building will command a much lower insurance rate and it will prove more satisfactory in many respects. Where a warehouse is not exposed within 100 feet, it is well to consider Standard I. A building conforming to that standard, but with a storage capacity of 1,000 bales, can be constructed for less money than where the outside walls are of standard brick construction. There would be only a slight difference in insurance rates.

STANDARD IV.—COTTON WAREHOUSE WITH OPEN COURT OR YARD.

Construction of building.—The outside brick walls should be not less than 13 inches thick, with or without a standard parapet, for a one-story building. (See p. 32 for required increase of thickness for additional height.) The roof should be of slate, metal, or standard composition. The building must be subdivided into compartments with a storage capacity not exceeding 1,000 bales each, or 72,000 cubic feet. The division walls should be of brick not less than 17 inches in thickness, and should rise at least 2 feet above the roof and extend at least 3 feet beyond the apron of the roof. The joists of compartments should rest on ledges, metal hangers, or metal wall plates. Each compartment should have one or more outside (not court) standard doors, not more than 40 feet apart, opening outward. The floors should be of earth, shell, concrete, or other noncombustible material. The standard width of the open court from shed to shed is 100 feet or more. In figure 4 is shown an approved diagram for this type of warehouse.

Doors to court.—Sliding doors to the open court should be of light frame construction, covered with approved terneplate, with single hook joints running horizontally and double lock seams running vertically on each side. The space between the two layers of tin should be filled with asbestos, magnesia, or some similar fire-resisting substance. A rolling, corrugated steel shutter which can be easily rolled or pulled down may be used in lieu of sliding doors. All sliding doors must extend at least 3 inches over the masonry at the sides and top of doorway openings and lap over each other at least 6 inches. The rail or track should be of wrought iron, secured to the walls with bolts passing through the walls, and fastened with washers and nuts. The hangers should be of wrought iron and fastened to the door by bolts passing through it and secured with nuts. Binders of iron, secured to the masonry in the same manner as catches and hanger blocks, should be used. The binders should be so placed at the top as to prevent the doors from rolling off the track at either end, and at the bottom to hold the door in position when closed.

Fire protection.—A connection of not less than 6 inches with a city main of at least equal size should be required. One standard fire hydrant should be provided for each three compartments or fraction thereof, with not less than 100 feet of 2½-inch cotton, rubber-lined hose attached to each hydrant at all times. A standard hose house, fully equipped, should be erected over each hydrant. Six or more fire pails filled with water should be suspended in front of each standard compartment and press room, and a proportionately larger number when the compartment exceeds the standard. A sufficient number of casks filled with water should be kept outside the door of each compartment, and three casks of water should be placed inside of each compartment. A watchman should be constantly on duty day and night, and should be provided with an approved watch clock, or report to an approved central station.

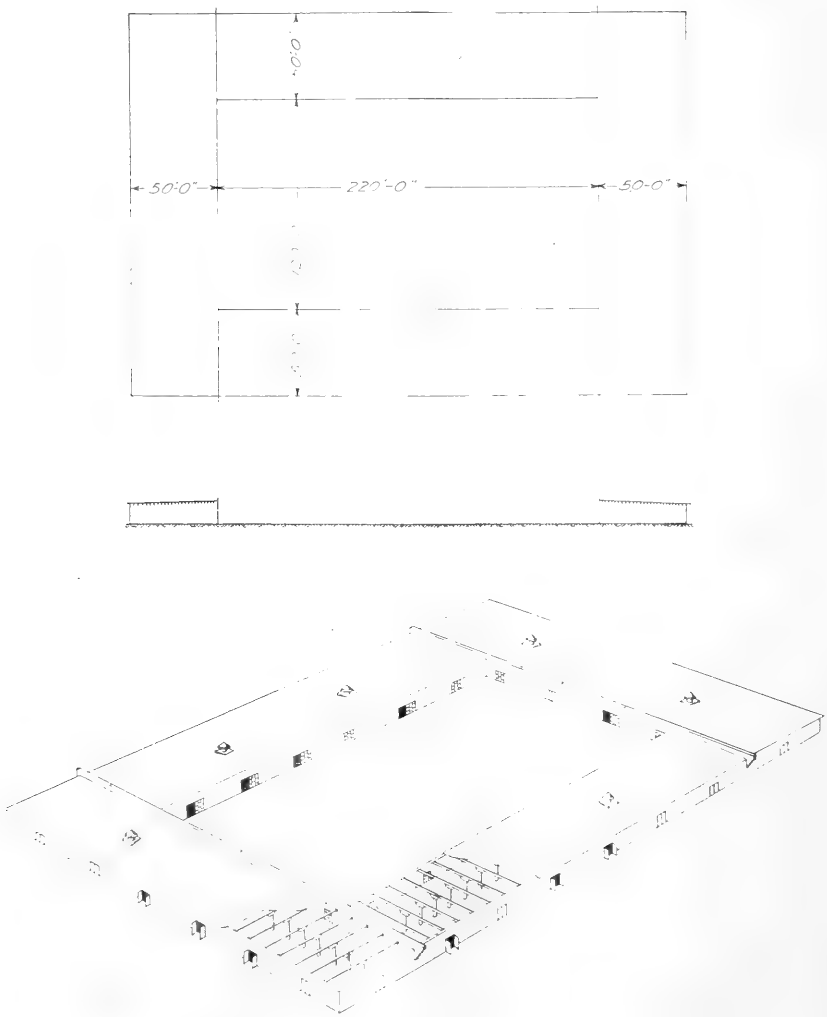


FIG. 4.—Cotton warehouse with open court or yard.

Samples.—Samples of cotton on storage should be kept entirely away from the warehouse, so as to more certainly insure their preservation in case of loss of cotton.

Smoking.—No smoking in or about the warehouse will be warranted in the insurance policy.

Compress.—Where a compress is connected with the foregoing standard warehouse, the boiler and machinery should be separated by walls not less than 17 inches thick, which should rise above the roof at least 2 feet. All openings in this wall should have standard fire doors on each side of the walls. These doors should be closed at all times when the compress is not in operation. All openings in the outside walls on, to, or overlooking the platform should be protected by single fire doors. The compress tower should be of all-metal or other noncombustible material.

Cotton in court.—Storage of cotton in courts is prohibited by a condition in the policy unless the warehouseman states at the beginning of the season that he wishes to use the court for storing, in which case the risk is rated for its full capacity, and such rating is not to be changed during the season unless it has been in effect at least 90 days.

SCHEDULE FOR RATING.

	City.		Town.	
	First class.	Second class.	Third class.	Fourth class.
Basis rate	$1.15	$1.25	$1.35	$1.50

This schedule of rates is subject to material reduction if the property is protected with standard automatic sprinkler equipment.

Add for deficiencies as follows:

1. Height:	
For two-story building	$0.10
For three-story building	.25
For four-story building	.50
For five-story building	.75
2. Variation from standard as to joist supports	.10
3. Openings to open court not protected by standard sliding doors or doors not standard	.25
4. Outside brick walls of less than 13 inches thickness	.25
5. For frame or ironclad outside (not court) walls	.75
6. For outside concrete-block walls (not court)	.50
7. Division walls, not standard	.25
8. Shingle roof or composition roof, not standard	.25
9. Excess in capacity of compartments and (or) warehouses and (or) courts:	
Over 1,000 bales and not exceeding 1,500 bales	.25
Over 1,500 bales and not exceeding 2,000 bales	.50
Over 2,000 bales and not exceeding 2,500 bales	.75
For each 1,000 bales additional	.25
10. Variation from standard as to outside doors (number)	.05–.15
11. Floor other than standard	.25
12. Private fire protection, none or not standard	.25
13. Fire pails and casks of water, insufficient supply (i. e., less than 6 casks and 12 fire pails for each 1,000 bales capacity)	.50
14. No watchman and approved watch clock	.50
15. Storage of lime or oils or use of any portion of building for stabling purposes or for "camping"	.50
16. Accumulation of loose cotton on floors or in other than closed bins	1.00

Deduction for chemical fire engines will be made as outlined in Standard I.

ADAPTATION OF STANDARD IV.

The open-court warehouse has very much the same use as Standard III. This warehouse is readily adaptable for use as a large public storage plant. This is especially true where the house occupies a full block. Where available land is in a narrow strip, it is frequently necessary to use Standard III, but in most cases where the warehouse has a storage capacity of not less than 10,000 or 15,000 bales it is advisable to use the open-court type.

STANDARD V.—STANDARD FOR HOLLOW-SQUARE OR OPEN-COURT WAREHOUSE OF FIRE-RESISTIVE CONSTRUCTION.

Construction of building.—This standard requires that the building should be constructed of reinforced concrete or standard brick throughout. The building should be constructed of an approved mixture of concrete (where concrete is used), properly reinforced with steel. Concrete blocks (whole or hollow) will not be considered reinforced. The area of any compartment should not exceed 2,950 square feet (59 by 50 feet) and the area of any compress compartment should not exceed 5,644 square feet (83 by 68 feet). (See fig. 5 for approved diagram). The height of any storage compartment should not exceed 13 feet 8 inches at the lower side or 16 feet 8 inches at the higher side.

Walls, doors, etc.—The outside walls should be at least 9 inches thick if concrete, or 13 inches thick if brick. Division walls should be 4 inches thicker than required for outside walls. The wall around the compress tower above the main roof should be 6 inches thick and should be constructed of reinforced concrete. All walls should have parapets 3 feet above the roofs of the same thickness as the wall. The parapets should be parallel with the contour of the roof and properly coped if built of brick. The floors should be of noncombustible material, with no air space underneath. To meet the standard, the building should have a concrete roof 4 inches thick, covered with approved composition roofing. All columns, girders, and cross girders supporting the roof should be of reinforced concrete.

No windows should be allowed except in the office and compress tower. Doors should be allowed only in outside and court walls, and these should be fully standard in all respects. Each storage compartment should have one or more standard fireproof doors, not more than 50 feet apart, opening outward. On the court side of the walls the doors must be placed before each tier of cotton. The court should be at least 200 feet wide, and no combustible material of any kind should be permitted in the court.

Arrangement, etc.—Not over 600 bales should be stored in any one compartment. The cotton bale should be laid flat on the side, and piled not to exceed 5 bales high. The sizes listed above will allow the storage of 600 standard bales, five tiers high. 120 bales to the tier. Loose cotton should not be allowed to accumulate, but should be picked up before closing the compress and placed in an

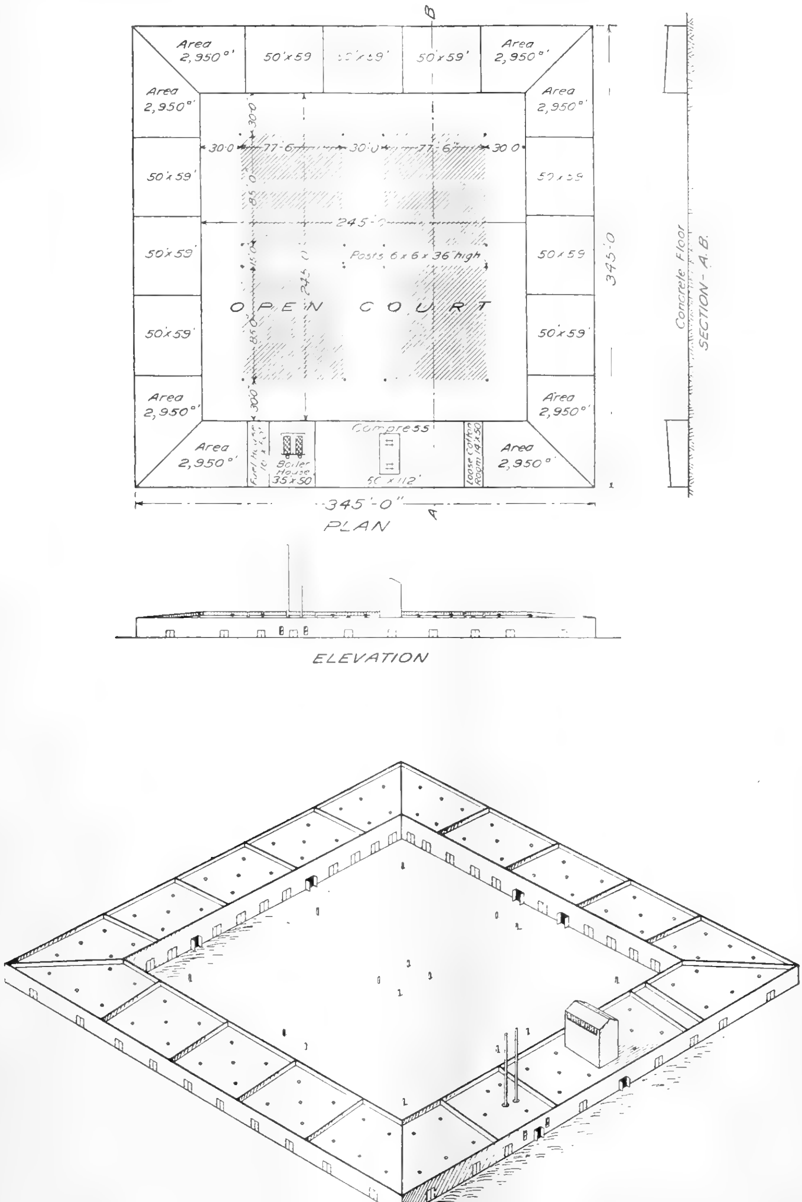


FIG. 5.—Standard for hollow-square or open-court warehouse of fire-resistive construction.

approved loose room with the samples. The records also should be kept a safe distance from the storage compartments. Cotton left in the court over night should not be piled or headed, and should be covered entirely with tarpaulins, properly battened down to prevent the wind from blowing them off the cotton. A clear space of 30 feet should be maintained between any cotton in the court and also in front of the compartments. A 15-foot aisle should be maintained longitudinally through the center of the court and a 30-foot aisle across the center of the court.

Boilers, fire protection, etc.—The boilers should be in a separate compartment of standard construction and should be well ventilated. Provision should be made for keeping fuel, oils, and waste in a safe place. Approved ash cans should be provided in order to prevent fire from this source. This standard also requires that a watchman with an approved clock should be on duty at all times when the plant is not in actual operation. A sufficient number of casks and pails should be placed in each compartment, in front of the compartments, and also in the open court. Yard mains should have a connection at least 6 inches in diameter with a city main of the same or greater diameter. A sufficient number of two or three way fire hydrants should be installed, as designated by the underwriters having jurisdiction, and be so located that the required number of standard fire streams can be brought to bear on all sides of the plant. Hydrants should be located 50 feet from the building and not over 200 feet apart. When automatic sprinklers are to be installed, plans and specifications will be furnished without cost upon application to underwriters.

SCHEDULE FOR RATING.

	Building.	Contents.
Basis rate:		
600 bales capacity	$0.68	$0.85
960 bales capacity	.85	1.10
For end of open court not closed by 7-foot close fence, add	.10	.10
For locomotives passing within 80 feet of open end, add	.50	.50

This schedule of rates is subject to material reduction if the property is protected with standard automatic sprinkler equipment.

Deduction for chemical fire engines is the same as outlined for Standard I.

ADAPTATION OF STANDARD V.

This type is used largely in cities by companies that try to give the most efficient service possible. It is needless to say that such a building commands a very low rate of insurance. Some compartments in such a house are frequently used for storage of cotton, while others in the same building may be used for storing merchandise and various other products. The first cost of such a building is high, but when the fact that the cost of insurance is greatly reduced and that the building will last almost indefinitely is taken into consideration, it will be seen that it is economical in many cases to erect a building of fire-resistive construction.

STANDARD VI.—STANDARD FOR SINGLE OR COMPARTMENT WAREHOUSE OF FIRE-RESISTIVE CONSTRUCTION.

In thickness of walls, roofs, floors, materials used, etc., this standard is practically the same as Standard V. The area of each single warehouse or compartment is 6,405 square feet (105 by 61 feet). The height of any single warehouse should not exceed 7 feet on the lower side and 10 feet on the higher side. Each single warehouse

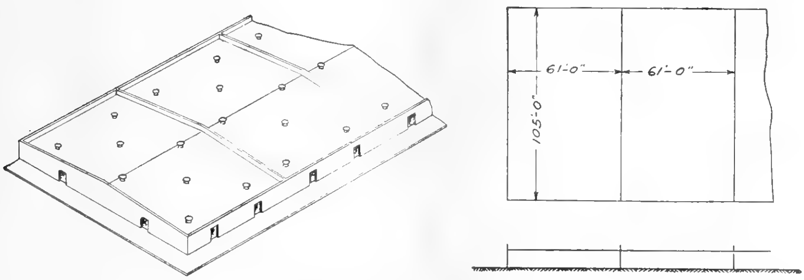


FIG. 6.—Standard for single or compartment warehouse of fire-resistive construction.

should have eight sliding doors, two to each wall. Not over 600 bales of cotton should be stored in any single warehouse or compartment, and they should be stored standing on end, one bale high only. A separate compartment should be provided for loose cotton, samples, records, etc. An approved diagram of this warehouse is shown in figure 6.

SCHEDULE FOR RATING.

	Building.	Contents.
Basis rate:		
600 bales capacity	$0.60	$0.85
960 bales capacity	.85	1.10

This schedule of rates is subject to material reduction if the property is protected with standard automatic sprinkler equipment.

Deduction for chemical fire engines is the same as outlined for Standard I.

ADAPTATION OF STANDARD VI.

This type of warehouse is used in much the same way as Standard V. However, Standard V is used chiefly in connection with compresses where a large amount of cotton is handled. Standard VI may or may not be used in connection with such a compress. Houses of this type are used generally by smaller plants.

STANDARD VII.—OPEN-SHED COMPRESSES AND PLATFORMS AND YARDS ATTACHED.

The open shed may be composed of one or more compartments. The storage capacity of no compartment should exceed 5,000 bales, or 55,000 square feet. Each compartment should be separated by standard brick division walls, 17 inches thick, without openings. The floors should be of heavy plank, laid on the ground with no space underneath. The roof should be of light frame construction, covered with gravel or approved composition. The roof and floor should be supported independently of the brick division walls. Supporting joists or timbers may rest on corbels of division walls and be entirely self-releasing. Such sheds should have hydrants with not less than a 6-inch connection with city mains, and a sufficient amount of hose should be provided. Hose houses, built in conformity with national board requirements and with full equipment, such as wrenches and lanterns, should be placed over each hydrant.

SCHEDULE FOR RATING.

	City.		Town.	
	First class.	Second class.	Third class.	Fourth class.
Basis rate	$2.25	$2.50	$2.75	$3.00

This schedule of rates is subject to material reduction if the property is protected with standard automatic sprinkler equipment.

Add for excess capacity as follows:

Over 5,000 and not exceeding 6,000 bales	$0.10
Over 6,000 and not exceeding 7,000 bales	.25
Over 7,000 and not exceeding 8,000 bales	.50
Over 8,000 and not exceeding 10,000 bales	1.00
Over 10,000 and not exceeding 15,000 bales	2.00
Over 15,000 bales	3.00

Add for deficiencies as follows:

1. Fire protection, none or not standard	$0.25
2. Compress boilers not cut off by 17-inch brick wall parapeted 3 feet above roof, and (or) openings not protected by standard double fire doors	.50
3. Less than 6 casks and 12 fire pails, filled with water, for each 1,000 bales capacity	.50
4. No watchman and approved clock	.50
5. Storage of lime or oils or use of any portion of building for stabling purposes or for "camping"	.50
6. Accumulation of loose cotton on floors or yard or in other than closed bins	.50

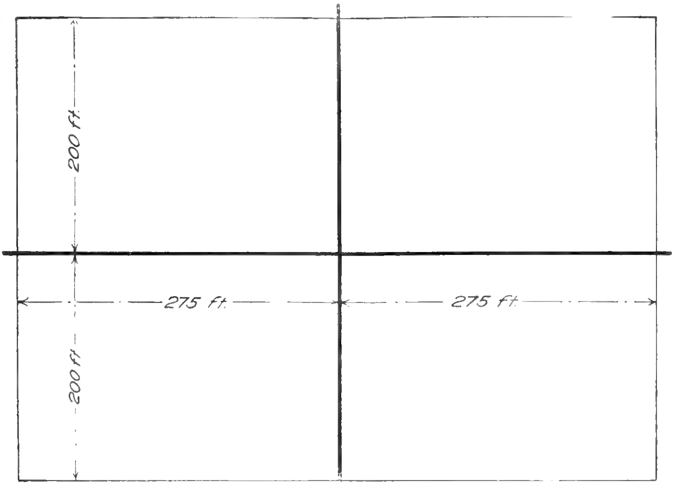
Deduction for chemical fire engines is the same as outlined for Standard I.

ADAPTATION OF STANDARD VII.

These sheds are used frequently in connection with compresses. In figure 7 is shown a complete and approved arrangement of such a shed with four compartments. These sheds have a very low cost compared with their storage capacity, but insurance rates are so high that they are not usually considered economical, especially when cotton is stored any considerable length of time. Much of the cotton handled at such a plant, however, is considered in transit and is covered by "floaters." In such cases a cheap shed is economical.

STANDARD VIII.—EMERGENCY SHEDS.

The specifications for emergency sheds given here are recommended by the Southeastern Underwriters' Association. These sheds should be located at least 100 feet in the clear, not being exposed to passing locomotives or other sheds or buildings. A diagram of the construction and arrangement of a group of emergency sheds is shown in figures 8 to 11.



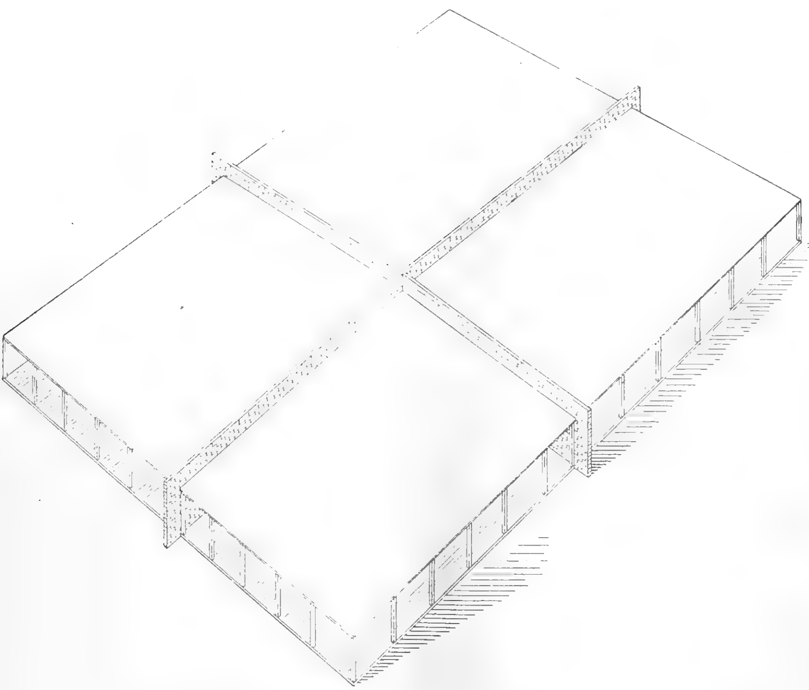


FIG. 7.—Open shed compresses and platforms and yards attached.

Construction.—These sheds or units should be constructed of light framework, each shed or unit being approximately 16 by 35 feet. The roof should be of joist construction, covered with approved composition roofing and supported by eight posts. Six of the posts should be 4 by 4 inches by 6½ feet long and the other two should be 4 by 4 inches by 27 feet long. Three posts should be placed at each end, supporting the eaves of the shed, which should extend within 4 feet of the ground. Two posts in the middle of the shed should support a 2 by 6 inch ridgepole. All posts should be set 12 inches in the ground. The sides and ends of the sheds may be open if not exposed within 100 feet to a railroad main line or open-end switch tracks. It is recommended, when feasible, that composition roofing should be

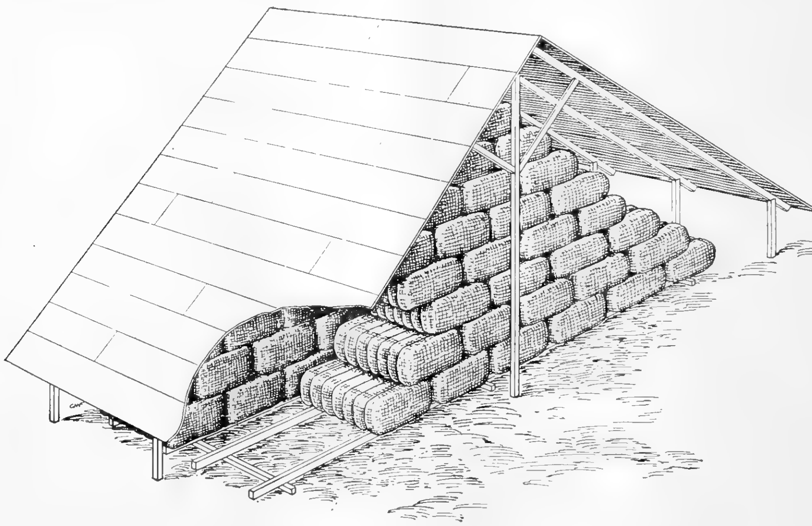


FIG. 8.—Emergency sheds—single unit.

used to inclose the ends of the shed from the peak of the roof down to within 4 feet of the ground, in order to protect the cotton entirely from weather. Metal sheets should not be used for inclosing the ends or sides of sheds. (A single unit, or shed, is shown in figure 8.)

Arrangement of cotton.—Cotton to be stored in sheds (units) should be arranged in two tiers (see fig. 11), the bales forming each tier being placed end to end. No tier should exceed 36 bales. The bottom layer of each tier should contain 8 bales. Each layer from the bottom up should contain 1 bale less than the layer next below, no tier being more than 8 bales high. The total number of bales in any shed or unit should not exceed 72.

The tiers should be supported on stringers, as follows: There should be three 4 by 4 by 10 inch mud sills laid on the ground crosswise with the shed and lengthwise with the bale or at right angles to the line of tiers. (See figs. 8 and 11.) These in turn should support four 4 by 6 inch by 15 foot stringers laid at right angles to the mud sills and spaced about 3 feet apart so as to properly support the bales. (Four of these stringers are required for each tier, as it requires two lengths to one end of the shed.) The bottom line of the lower layer of cotton should be at least 10 inches above the ground and should be piled in tiers so arranged that the eaves on the extreme ends of the roof extend 3 feet beyond the outer line of cotton.

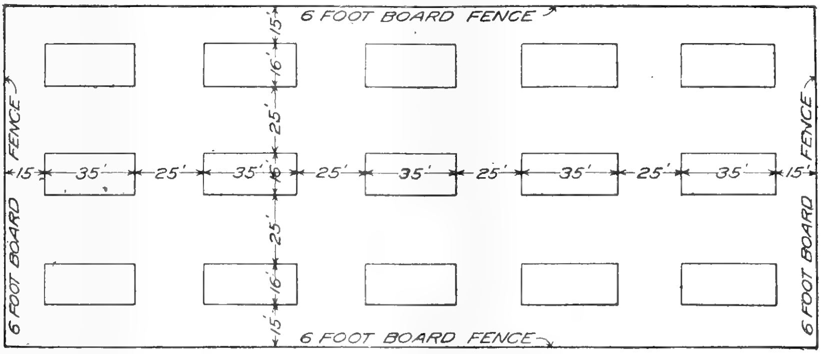


FIG. 9.—Emergency sheds—plan for 1 group of 15 units.

Arrangement of units.—The units should have at least 25 feet of clear space on all sides and ends and should be arranged in groups of not exceeding 15 units. (See fig. 9.) These groups should be inclosed with a 6-foot board fence, with 15 feet clear space between the fence and the ends or sides of the sheds or units. (See fig. 10.)

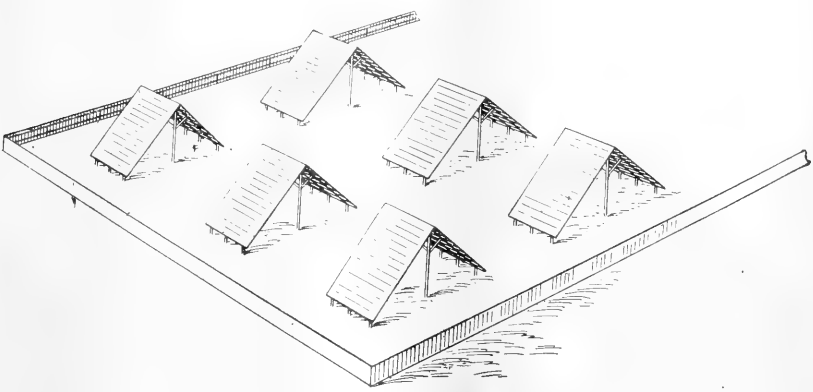


FIG. 10.—Emergency sheds—isometric view of sheds and fence.

A group of 15 units requires an inclosed area of 128 by 305 feet. Where more than one group is used they should be at least 100 feet apart. Two or more groups may be included in the same inclosure, provided 100 feet clear space is maintained between each group.

The insurance policy covering risks outlined above should have a warranty attached showing that not exceeding 72 bales will be stored in any one unit and not exceeding 1,008 bales in any one group.

SCHEDULE FOR RATING.

The basis rate on cotton stored in emergency sheds as outlined is $1.75 in cities or towns. Where such sheds do not have standard fire protection, or the requisite number of casks and pails, 25 cents must be added to this basis rate. Where no watchman with an approved clock is on duty, an addition of 25 cents must be made.

ADAPTATION OF STANDARD VIII.

Emergency sheds are not to be recommended as a place for permanent storage. It may be seen readily that these sheds require

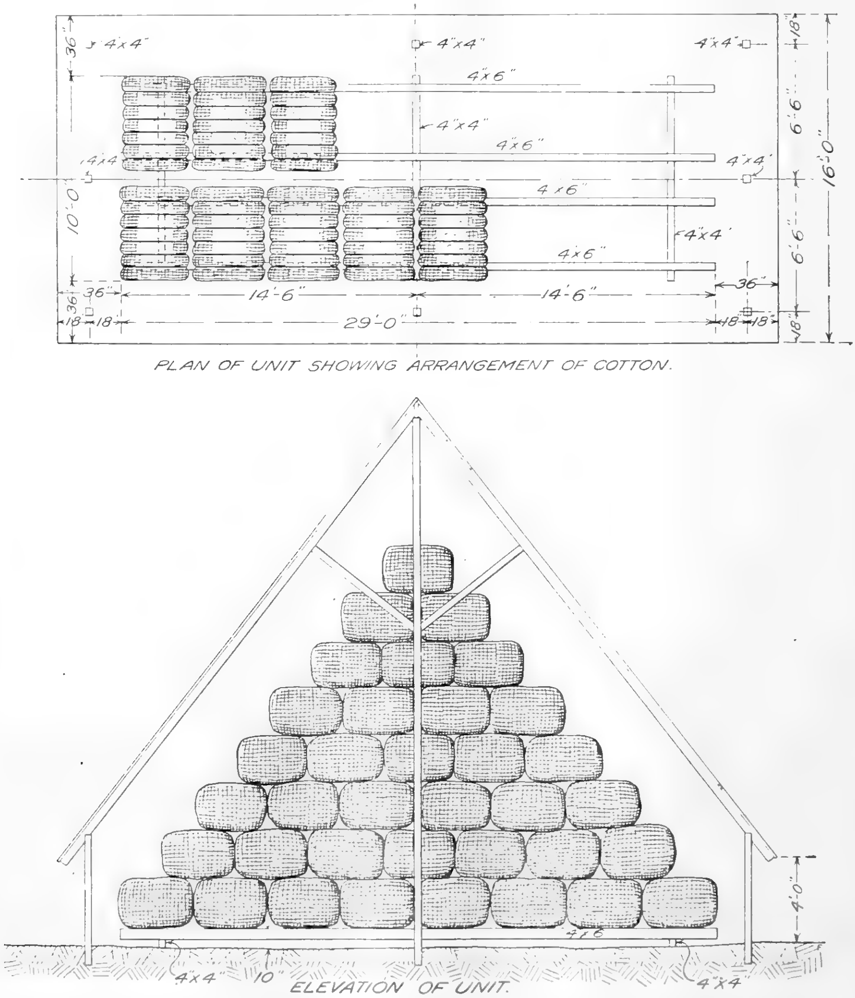


FIG. 11.—Emergency sheds—arrangement of cotton in unit.

a large amount of land and would be very inconvenient where cotton had to be handled frequently. When conditions are such that a considerable amount of cotton must be stored pending better market conditions, but where permanent storage is not desirable, it might be well to erect such sheds, inasmuch as the original cost of construction is very low. As the name indicates, they are intended entirely to meet emergencies, and not as permanent storage sheds.

Estimate of bill of material and approximate cost for building one shed.

770 feet lumber, at $18 per M	$14.00
Nine rolls roofing, at $2.50 per roll	22.50
Nails	1.00
Labor	10.00
Total approximate cost for one shed	47.50

Estimate of bill of material and approximate cost of building a group of sheds.

Group of 15 sheds, at $47.50	$712.50
5,049 feet lumber for fence, at $18 per M	91.00
Nails for fence	2.00
Labor for fence and 15 units	175.00
Total approximate cost for group	980.50

MISCELLANEOUS FIRE-INSURANCE SCHEDULES.

Schedules for rating cotton when stored in streets and various places other than the standard warehouses described are given below:

COTTON IN STREETS.

Rate in first-class city, if within 500 feet of standard city hydrants	$4.25
Rate in second-class city, if within 500 feet of standard city hydrants	4.50
Rate in third-class town, if within 500 feet of standard city hydrants	4.75
Rate in fourth-class town	5.00

COTTON IN YARDS AND IN OPEN OR COVERED PLATFORMS, NOT EXPOSED WITHIN 100 FEET BY COMPRESS (STORAGE LIMITED TO 5,000 BALES).

	City.		Town.	
	First class.	Second class.	Third class.	Fourth class.
Basis rate	$2.00	$2.25	$2.50	$2.75

Add for excess capacity as follows:

Over 5,000 and not exceeding 6,000 bales	$0.10
Over 6,000 and not exceeding 7,000 bales	.25
Over 7,000 and not exceeding 8,000 bales	.50
Over 8,000 and not exceeding 10,000 bales	1.00
Over 10,000 and not exceeding 15,000 bales	2.00
Over 15,000 bales	3.00

Add for deficiencies as follows:

1. Fire protection, none or not standard	$0.25
2. Less than 6 casks and 12 pails of water for each 1,000 bales capacity	.50
3. No watchman with approved watch clock	.50
4. Storage of lime or oils or use of any portion of premises for stabling purposes or for "camping"	.50
5. Accumulation of loose cotton on yard or platform or in other than closed bins.	1.00
6. If inclosed by barbed-wire fence	.25

Make deductions as follows:

7. If inclosed by 7-foot high close board fence, deduct	.15

Deduction for chemical fire engines the same as in Standard I.

COTTON IN BALES ON RIVER BANKS AND PLANTATIONS.

In buildings other than gin houses.

1. Standard mill construction with fire walls and approved roof	$2.50
2. Same as 1, with shingle or unapproved roof	2.75
3. Frame building with corrugated iron sides and approved roof	3.00
4. Wooden building with approved roof	3.25
5. Wooden building with shingle or unapproved roof	3.50
6. Cotton in the open	3.50

On cotton wharves.

Standard: One-story frame or iron-clad building, not exceeding 25,000 square feet, under first-class city fire protection. Private fire protection to conform to standard requirements. Fire pails every 50 feet; watchman and approved watch clock.

	First-class city.	Second-class city.	Third and fourth class towns.
Basis	$2.25	$2.40	$2.50

Add for deficiencies as follows:

1. Excess area, for each 5,000 square feet above 25,000 but not to exceed 50,000 square feet	$0.01
For each 10,000 square feet in excess of 50,000 square feet	.01
2. Roofing not standard	.25
3. For second story (no charge for office occupancy above first story)	.10
4. Heating by stoves unsafely arranged	.25
5. Lights, kerosene oil, acetylene, or gas, with swinging brackets	.10
6. Steam hoisting engine with boiler, or wood cutting on pier	.25
7. If boiler stack is without spark arrester	.25
8. Age and general condition	$0.05 to .25
9. No standard private fire protection (two water supplies required)	.25
10. Casks of water and fire pails, none	.10
11. Watchman and approved watch clock, none	.25

Make deductions as follows:

1. For uncovered wharf	.50
2. If covered pier of steel-frame construction throughout	.25
3. For pier built all on land or filled in underneath, deduct for contents rate	.10
4. For fire-boat protection, according to efficiency	$0.05 to .25
5. For piers having all reinforced concrete foundations and piling (on piers only; no deduction for contents	.25

Deduct for chemical fire engines the same as in Standard I.

GENERAL CONSIDERATIONS RELATING TO COTTON STORAGE AND FIRE INSURANCE.

CLASSIFICATION OF CITIES AND TOWNS.

For convenience in quoting insurance rates, cities and towns are divided into four classes:

First-class city.—This class requires that the city have an efficient, fully paid fire department, with standard equipment throughout, and waterworks that will insure an ample supply of water under the proper pressure at all times. The streets must be paved and standard in width, an efficient police force must be maintained, and the city must have proper ordinances for assuring caution in regard to fire. It is also necessary for a first-class city to have well-defined fire limits.

Second-class city.—The requirements for a second-class city are very much the same as for the first-class, except that the fire company may be only partly paid, but it must be in charge of a competent chief. The streets need not be paved, and the requirements in regard to equipment are not so rigid as in class 1.

Third-class towns.—In this class the fire company is voluntary, but must be under a competent chief. This voluntary fire company must be provided with adequate hose wagons or hose reels and a sufficient quantity of standard $2\frac{1}{2}$-inch cotton hose. The town must have standard waterworks and a fire alarm centrally located.

Fourth-class towns.—This class includes towns and villages having no approved waterworks or fire department.

INSURANCE RATES.

Explanation.—In discussing insurance rates every effort has been made to give authentic information. The data which have been used are taken from the rates quoted by the Southeastern Underwriters' Association. In many instances the exact language employed in "Rates, rules, and forms" has been used. After this material was prepared it was submitted to experienced insurance men. It is confidently believed that every statement made is correct, but at the same time no responsibility is assumed for the correctness of the rates quoted in this bulletin.

Segregation.—In controlling or preventing fires one of the fundamental principles is segregation. This is accomplished in various ways. One way is to erect small buildings a sufficient distance from each other or from other buildings, so that if one house be completely burned none of the others will be affected by the fire. When larger buildings are erected, division or fire walls divide the space into compartments. A fire in one compartment may destroy all of the contents and the combustible portion of the building without affecting other adjoining compartments.

This plan of segregation is very important in the case of cotton, for it is of such an inflammable nature that it produces a flash fire. This is the case particularly with cotton in the form in which it is ordinarily stored. It is not properly wrapped at first, and, after it has undergone frequent samplings it reaches the warehouse in a very ragged condition. Much of the lint is not covered at all, and this loose lint is sometimes hanging from the bale. These methods leave the bale in such a condition that a spark will sometimes start a blaze which will flash over a loose lot of cotton in a very short time. When hundreds of bales are stored in one compartment this fire will flash from one bale to the other and frequently will extend over a lot of a thousand bales in a very few minutes. It can be seen readily that cotton stored in large quantities in a single compartment would be subject to a very costly fire, but a large warehouse might be divided into several smaller compartments and so avoid an extensive fire. This is the principle on which the insurance companies base their specifications.

Automatic sprinklers.—The automatic sprinkler also has proved to be of very decided advantage in protecting cotton warehouses from fire damage. By means of automatic sprinklers a fire automatically releases the water which is to isolate it. A detailed investigation of 90 fires in cotton warehouses under sprinklers shows that the average number of heads opening was 13.5 per cent, while in 52 per cent of the cases less than 10 heads opened. Later in this bulletin a brief description of a modern sprinkler system is given, which will show just how this desirable end is accomplished.

A study of fires in cotton warehouses which are protected by automatic sprinklers shows that out of a total of 159 fires, 69, or 43.4 per cent, were entirely extinguished by the sprinklers, and 74, or 46.5 per cent, were successfully held in check, making a total satisfactory sprinkler record of 143 fires, or 89.9 per cent. Of the 16 fires which were classed as unsatisfactory, in 8 cases the water was shut off from the sprinklers; in 2 cases the water supply was defective; 1 fire was due to faulty building construction; and 3 to obstruction to distribution. Of all of these cases, 13 were really not attributable to the standard sprinkler equipment in the standard warehouses, and in only 1 case was it found that the hazard of occupancy was too severe for the average sprinkler system.

LOCATION OF A WAREHOUSE.

It is very important to have a cotton warehouse conveniently located on a sidetrack. This saves drayage, which is a considerable item when the business is large. However, the warehouse should not be within 100 feet of the main line of a railroad or a sidetrack which extends beyond the building, for if it is so located the insurance rate will be increased. This is avoided by having the warehouse at or near the end of the sidetrack.

Many companies have made the mistake of deliberately locating the warehouse away from the business section. This is a serious mistake, for several reasons: First, there is the cost of drayage. In the second place, persons who are not directly interested in such a warehouse will patronize an establishment nearer the business center.

In many cases warehouses belonging to farmers' organizations have been located in the suburbs, or even in the country. It frequently happens that the cotton buyers of the town would use this space if it had been located properly, but they find it impossible to dray their cotton to the edge of town for storage, with the prospect of hauling it back to the station when it is sold. This causes the failure of many promising farmers' organizations.

PLATFORMS.

It is desirable to provide ample platform space at every warehouse. There should be a convenient place for unloading cotton from wagons, and, where cotton is shipped in, provision should be made for unloading it from cars. It is also necessary to have ample room for trucking when cars are being loaded or unloaded. In many markets cotton is sold by the farmers on public platforms near the warehouses. In such cases platforms should be of adequate proportions and so located that the cotton may be conveniently trucked to the warehouse or to the railroad platforms for loading. The mistake is made frequently of building platforms which are entirely too narrow next to the railroad. When different lots of cotton are being arranged for storage or for shipment, it is very desirable to have sufficient space to accommodate several hundred bales in addition to room for trucking. There are times during emergencies when such space can be used to advantage for temporary storage.

In figure 12, page 32, is shown a view of a well-arranged warehouse conforming to Standard I. It will be seen that there is ample platform space on either side and that the warehouse is not exposed by other buildings. Fully equipped hose houses are placed at opposite ends of the compartments. This view also shows the proper method of storing cotton, the bales being placed on end only one bale high, and a clear passage is maintained from one end of the compartment to the other. The view also shows in a very general way an automatic sprinkler system. In this case the tank is placed on the extended walls of the building, which arrangement is economical in that it saves in the cost of constructing a tower for the tank, but it is not altogether as satisfactory as a separate steel tower.

SALVAGE.

Another important consideration is the salvage. While loose cotton burns very rapidly, it frequently requires several days for a bale to damage seriously. In many fires the outside of the bales is burnt and damaged to a considerable extent, but where ample provision is made for removing the cotton from the burning building, it is frequently possible to save at least 50 per cent of the original value. It is for this reason that all standards require many doors so that the cotton may be removed rapidly during the fire. For the same reason a risk takes a much higher rate when the warehouse is surrounded by a barbed-wire fence or when there are any other obstructions that might hinder the prompt removal of the cotton.

HEIGHT OF WALLS.

In all of the foregoing types the thickness of wall mentioned has been for buildings one story high. The standards for fire walls for buildings of different heights are given below. In the table the thickness refers to the outside walls. In all cases the division walls between the storage compartments should be 4 inches thicker than outside walls.

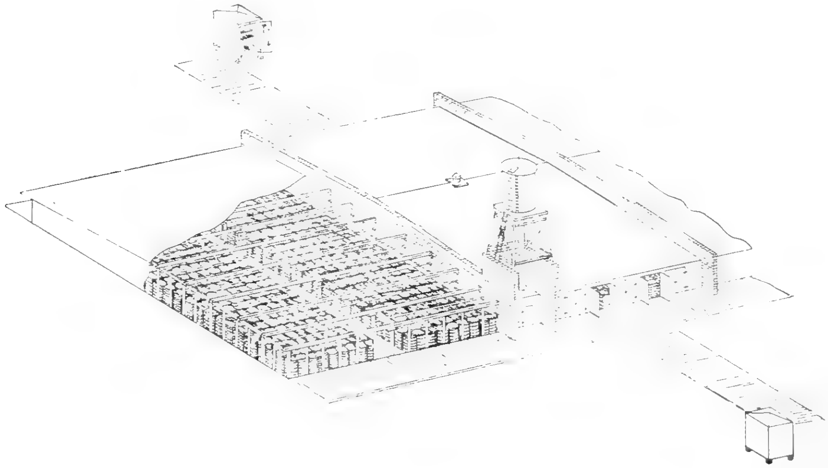


FIG. 12.—Standard cotton warehouse fully protected, showing the proper method of storing.

Standard fire walls.

Height of building.	Thickness of outside walls, in inches.					
	First story.	Second story.	Third story.	Fourth story.	Fifth story.	Sixth story.
One story	13					
Two stories	17	13				
Three stories	17	17	13			
Four stories	22	17	17	13		
Five stories	22	22	17	17	13	
Six stories	26	22	22	17	17	13

FLOORS.

All of the standards recommended by the insurance companies require that floors be of concrete, dirt, shell, or other incombustible material. Many warehousemen object to any of these floors for the reason that when cotton is stored on such floors for any length of time "country damage" usually occurs. This is undoubtedly true in the case of dirt floors unless drainage is unusually good. Many of the best warehouses, however, have dirt floors. If the drainage is good, the cotton will not be damaged when stored temporarily. When it is to be stored for any length of time, it should be placed on timbers that will keep it well off the ground. Most warehouses keep a supply of skids or stringers, 6 by 8 inches or 4 by 6 inches. These timbers keep the cotton well off the ground, and there is no danger from damage from too much moisture. The great advantage of the dirt floor is the saving in cost of building and insurance. The dirt floor does not require such high walls as are required where a plank or concrete floor is used, and the cost of a standard floor such as cement or brick is very high. The insurance rate is 25 cents higher on plank floors.

Concrete.—There is a wide difference in opinion among warehousemen on the advisability of using concrete as a floor. In the first place, there is the very high cost. In the second place, it is contended that cotton will be damaged when stored in contact with such a floor. Others are highly in favor of using it and do not think that the cotton damages to any appreciable extent. It seems safe, however, to state that there is some danger unless there is perfect underdrainage. If a suitable space under the floor is built up with coarse, clean sand, as required by the standards, and a proper outlet is maintained for any water, it seems that damage from this source is almost negligible. If, however, the drainage is not sufficient, there will certainly be some damage. This is especially true if the cotton is too damp when stored. It is also claimed that cotton will lose weight when in contact with a concrete floor during excessively dry seasons.

Paving blocks.—Some warehousemen are now advocating the use of wooden paving blocks for flooring. This material is not included in the present standards of the underwriters' associations, but there seems to be no good reason why it should not be classed as fully standard. A floor made of this material would last indefinitely, and there would be apparently no danger of damage from excessive moisture nor loss from undue drying. The suggestion is certainly worth consideration by any who are preparing to build. The cost, however, would be rather high.

If for any reason a standard floor is not built, the owner should be very careful to have a good, substantial wooden floor. In the first place, substantial pillars of brick or other strong material should be used, and they should be placed often enough to make a strong foundation for the floor. Sleepers should be of the best material, not less than 6 by 8 inches in diameter. The flooring should be not less than 2 inches in thickness and should be splined or tongued and grooved. To get the best insurance rate, the space from the floor to the ground should be filled in with some noncombustible material. If this is not done it is essential that there should be no openings from this space to the outside of the building.

AUTOMATIC SPRINKLERS.

While it is not possible to give specifications for a system of automatic sprinklers, the installation of such systems in all cotton warehouses is urged. To do so means additional cost, but the saving in insurance will more than offset this cost of installation. The expenditure is fully justified by the protection given the cotton, which results in saving in the cost of insurance. Numerous warehouses have been found where the insurance rate has been reduced from $1.50 per hundred dollars to 30 cents. Many companies are now selling and installing these systems. Before anyone purchases he should have detailed specifications prepared, and these should be submitted to the underwriters having jurisdiction. The importance of this can hardly be overestimated. An owner of a warehouse recently had a sprinkler system installed in his warehouse, expecting to get the usual reduction in insurance rate. However, it developed that the capacity of his tank was only 3,000 gallons, while the requirements called for a minimum capacity of 25,000 gallons.

History.—In connection with the discussion of the automatic sprinkler as a means of controlling fires, it is interesting to note the development of this system. Formerly there were many fires in cotton mills, especially in picker rooms, in which department much loose cotton is handled. Disastrous fires frequently start in the picker itself. This machine has spikes on a cylinder which tear or loosen the cotton. When one of these spikes becomes slightly bent, it may touch another spike on the machine, and the resulting spark usually starts a fire. For a long time there was no protection against such fires except the casks of water and pails. Finally it became customary to provide this room with a crude sprinkler system. This consisted of numerous perforated pipes throughout the room. These pipes were connected with a supply of water. A valve on the outside of the building was designed to turn the water into the perforated pipes. Under this arrangement when a fire started some employee went out to the valve and turned on the water. This apparatus was a great improvement over the old condition, but it was weak in several respects. In the first place, the water was not turned on until some one went from the scene of the fire and opened the valve. Another very serious objection was that the water was applied to all portions of the room. This damaged the building, machinery, and cotton in places where it was not necessary, besides exhausting the water supply unnecessarily.

Description of a modern automatic sprinkler system.—The direct outgrowth of this crude arrangement was the present automatic sprinkler system. This system consists of a tank or other means of supplying water. Ordinarily it is a large gravity tank and has direct connection with at least one city main. Pipes connecting with this main are in all portions of the building. The water is distributed by sprinkler heads. These heads are so arranged that when they are heated to a certain degree they open and send out a considerable stream or spray of water Under good pressure one head will discharge some 40 or 50 gallons of water per minute. This system has two very important advantages over the earlier form. The water is liberated automatically—that is, when a fire starts the heat opens the heads and the water is turned on without the attention of any person. A second advantage is that only those heads near the fire are opened. This prevents damage to wares in other portions of the compartment and also conserves the water except for the particular space where the fire is burning.

The automatic sprinkler system in its latest development consists of a tank or other water supply of ample capacity—depending upon the amount of space protected by the system—proper connections with the city mains or other sources of water, sprinkler heads distributed over the building with the necessary water supply pipes, and an alarm which is set off automatically when a fire starts. If a dry-pipe system is used, in order to prevent freezing of the water in the pipe, the system requires draining after a fire, and the dry-pipe valve is then reset. The water pressure at the heads should be at least 15 pounds, which makes it necessary for the tank to be at least 30 feet above the highest head. A dry valve is not always used, except where there is danger that water will freeze in the pipes, and thus render the system worthless at a time when it might be needed. When it is possible, the system should have at least a 6-inch connection with the city main. The sprinkler heads should be distributed over the building in such a way that one head would cover a space of 65 to 90 square feet, depending upon the arrangement and construction of the building. These heads should be placed near the ceiling. If a fire occurs near the floor, the heat rises immediately, and the heads directly over the fire are opened automatically. It requires 155° to 165° F. to melt the solder and automatically release the water.

A fully protected warehouse which conforms in every respect to the requirements of the underwriters' association is shown in figure 13. When cotton is valued at 10 cents per pound, or $50 per bale, it is possible to insure it in this warehouse at the rate of 5 cents per bale per annum. This illustrates forcibly the advantage to be gained by conforming to the underwriters' standards and installing approved automatic sprinkler equipment, which effects a great saving in the cost of insurance.

FENCES AROUND WAREHOUSES AND COTTON YARDS.

It is very important that cotton stored in open sheds or yards should be fenced in. Such a fence should be made of good boards, securely nailed to railings, which are in turn fastened to strong posts. In other words, it should be a good, close, substantial board fence at least 6 feet in height. These fences prevent prowling, the careless throwing of cigarette stubs, and various other practices that frequently prove costly. It is usually possible to reduce insurance rates materially by taking this precaution. While it is not at all

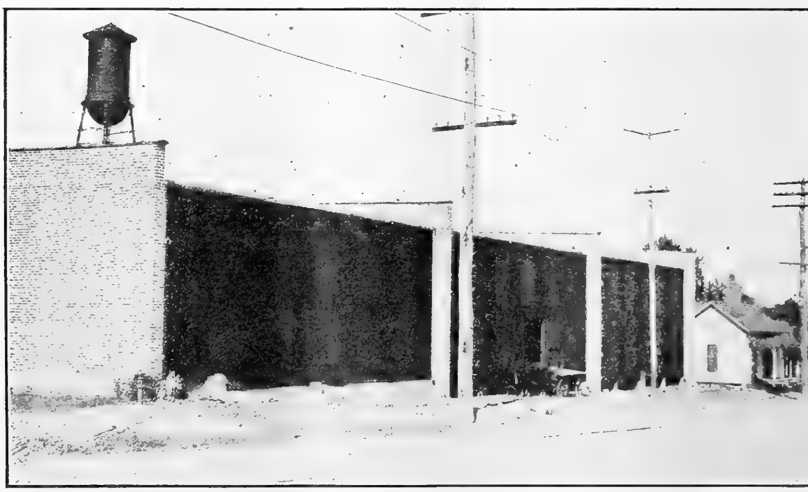


FIG. 13.—A standard two-story cotton warehouse.

essential, it would be well for such a fence to be erected around all warehouses, together with the adjacent yards that are used for handling cotton.

A wire fence should never be placed around yards or sheds, for it interferes with handling cotton during a fire, and consequently increases insurance rates.

FINANCIAL CONNECTION.

When the construction of a warehouse is being contemplated, it is well to take into consideration the financial assistance that probably will be extended by the banks to those who store cotton. It is frequently the case that owners store cotton primarily for the purpose of obtaining money for use until the conditions of the market are improved. If it were possible to obtain money on the best terms, much cotton would be stored which at present is allowed to damage and remain unprotected from fire and theft. Many companies get comparatively little business and eventually fail because the banks are not willing to advance money on cotton stored with them. This should certainly be taken into consideration when preparing to build a warehouse. If satisfactory financial connections can not be arranged, the chances are that the undertaking will prove a disappointment and the promoters will necessarily lose by making such an investment.

COOPERATION OF FARMERS.

Other investigations [1] have shown conclusively that most of the small warehouses located near the points of production do not pay for the operating expenses and deterioration of the property. For this reason very few companies in the small towns are inclined to operate warehouses that give adequate service. If the farmers in such a community wish to be assured of storage service at all times, they should form cooperative associations and build their own storage houses. In most cases such associations would not be expected to pay any dividends, but the farmers would be sure that they would have available storage space at all times, and in this way they would be independent of factors, merchants, and others who now control most of the storage space. If the farmers in such communities would go further and organize selling associations, it would be possible to employ an experienced cotton man who would be able to market the cotton more profitably than is now done. The cotton mills are saving considerable sums of money by cooperation in insurance. The mutual companies insure cotton belonging to mills for much less than it is necessary to pay when cotton is stored in a public warehouse. There is no reason why farmers should not save by cooperating in building and insuring their own cotton warehouses.

CONCLUSION.

An adequate system of storage houses is one of the most imperative needs of the South. Such an improvement would bring about an annual saving of millions of dollars from what is usually called "country damage." This change would also eventually bring about many reforms in the present method of marketing cotton. In addition to cotton, the South annually handles products worth hundreds of millions of dollars that would be stored if it were possible to do so under favorable conditions. There is also a great demand for storage space for merchandise and various manufactured products, such as fertilizers and farm machinery.

In concluding this discussion of the construction of warehouses, it is urged again that it is of the greatest importance that warehouses

[1] Nixon, Robert L. Cotton Warehouses: Storage Facilities now Available in the South. Bulletin 216, U. S. Department of Agriculture. 1915.

conform to the standards of the underwriters' association. These standards have been worked out very carefully and represent the best thought in protecting cotton from both fire and weather at a minimum cost. Many millions of dollars have been spent unwisely in the construction of warehouses that do not conform to these standards. A thorough survey made by this office shows conclusively that many of these houses cost more to build than they would if they had been made to conform to the recognized standards. Most warehouses, as they are now constructed, are not only subject to unnecessarily high insurance rates, but are usually costlier than those conforming to the standards, and the cost of handling cotton stored in them is unnecessarily high.

The diagrams in this bulletin should not be treated as plans for building. An attempt has been made to outline some of the essential features of each type. It is very important that a competent architect draw up specifications for any warehouse. While it will be necessary to pay a fee for this service, the plans will save a great deal in the cost of construction and insurance and add much to the value of the storage house by making it possible to handle cotton more economically. It is also important to have warehouses properly located. This is frequently the determining factor between success and failure. Many warehouses erected by cooperative organizations and by others have been so located that they are not available to a large majority of the people who frequently wish to store cotton. This has resulted in the failure of many such enterprises. Farmers should form cooperative organizations for building better storage houses where adequate facilities are not available on favorable terms.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 278

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief.

Washington, D. C. PROFESSIONAL PAPER. October 5, 1915

MISCELLANEOUS INSECTICIDE INVESTIGATIONS.[1]

By E. W. Scott and E. H. Siegler, *Entomological Assistants, Deciduous-Fruit Insect Investigations.*

CONTENTS.

INTRODUCTION.

Numerous experiments with miscellaneous insecticides and spray combinations, including tests of a new and promising arsenical, namely, arsenate of calcium, were conducted in connection with other work at the field station for deciduous-fruit insect investigations, at Benton Harbor, Mich., during the seasons of 1912, 1913, and 1914. Various homemade and proprietary insecticides, alone and in combination with other sprays, were tested in the laboratory and in the field. This work was done under the instructions of Dr. A. L. Quaintance, in charge of Deciduous-Fruit Insect Investigations, and much valuable assistance in carrying out the work was rendered by Messrs. J. H. Paine, H. G. Ingerson, and D. M. Hamilton.

EXPERIMENTS, 1912.

A series of poison-feeding experiments were made to determine the comparative killing effect of various arsenicals and also doubtful stomach poisons on different species of chewing insects. At the beginning of the tests 32 different materials were used, but since the

[1] See key to the table of insecticides on page 43.

Note.—This bulletin describes experiments with various chemicals, singly and combined, for the destruction of insect pests. It will be of interest to horticulturists in general and apple growers in particular.

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first few experiments showed that many of these were of little value as stomach poisons, their use was discontinued.

A few homemade preparations were tested in the course of these experiments. Those used in 1912 were arsenate of iron, arsenate of zinc, and arsenite of lime. The methods of preparation of these materials were as follows:

Arsenate of iron was prepared by dissolving 4 pounds of sodium-arsenate crystals and 4 pounds of iron sulphate each in 2 gallons of hot water. The iron-sulphate solution was then poured slowly into the sodium-arsenate solution, the solution being stirred vigorously at the same time. Arsenate of iron was used at a rate equal to 0.8 pound of sodium arsenate to 50 gallons of water for the ordinary strength.

The arsenate of zinc (homemade) was prepared in the same way as arsenate of iron, sodium arsenate and zinc sulphate being used, and the strength being based upon the sodium-arsenate content, the same as for arsenate of iron.

Arsenite of lime was prepared by boiling 2 pounds of white arsenic and 2 pounds of sal soda in 1½ gallons of water until thoroughly dissolved, and this was used to slake 4 pounds of stone lime. After slaking, enough water was added to bring the total to 2 gallons. This was used at the rate of 2 pints to 50 gallons of water, which is equivalent to one-fourth pound of white arsenic to 50 gallons of water.

LABORATORY TESTS.

During the season of 1912 the fall webworm (*Hyphantria cunea* Drury) was used for all the experiments, since this insect could be readily obtained in large numbers, and proved to be an ideal species for handling in the laboratory. Very young larvæ, usually 3 or 4 days old, were used in all the tests. The larvæ were fed with foliage of the wild black cherry (*Prunus serotina*), which was found to be a favorite food plant of the fall webworm in Michigan. Twigs having from 20 to 30 leaves each were sprayed by means of a large atomizer of the type in which quart jars are used as a container for the liquid, and the stems of the twigs were placed in small glass jars containing water.

After the spray had thoroughly dried, allowing from 6 to 12 hours, 20 insects were placed on the leaves of each twig. A large paper bag was then placed over the twig and held to the glass by means of a rubber band to prevent the escape of the larvæ. At each examination the bag was removed and the dead larvæ taken out and counted. When all the insects were dead or had pupated, as the case might be, the amount of foliage consumed was measured in square inches. A sheet of celluloid, cross-sectioned to 0.01 of a square inch, was utilized for this purpose. These measurements were easily taken where effective poisons were used, as the young larvæ died before very much foliage had been consumed. In other cases, where the entire leaf except the midrib and larger veins was consumed, the measurement was obtained by measuring an average-sized leaf and substituting it for the leaf which had been destroyed. Careful attention was given to the condition of the foliage throughout the experiments so as to supply the larvæ with palatable food at all times.

Experiment I.

COMPARISON OF THE KILLING EFFECT OF DOUBTFUL STOMACH POISONS WITH VARIOUS ARSENICALS ON LARVÆ OF THE FALL WEBWORM.

In this experiment the arsenite of zinc compounds and other proprietary insecticides were used at the strengths recommended by the manufacturers. The homemade arsenical compounds, where sodium arsenate was employed, were used at a rate to equal 0.8 pound sodium-arsenate content to 50 gallons of water, except in the case of arsenate of iron, which was used double strength. Arsenite of lime, homemade, was used at the rate of 2 pints to 50 gallons of water. All other compounds containing arsenic were used at a strength equivalent to 2 pounds of arsenate of lead paste to 50 gallons of water. These calculations were based upon a 15 per cent arsenic-oxid (As_2O_5) content in arsenate of lead paste. Compounds containing no arsenic were used at the rate of 6 pounds to 50 gallons of water. The larvæ used in this test were about 4 days old. The results are given in Table I.

TABLE I—*Tests of the killing effect of various arsenicals and doubtful stomach poisons on the fall webworm.*

[Experiment started July 13, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Name and dilution.	Dates of examination and number of larvæ dying on each date.																							Number of larvæ pupated.	Total number dead.	Number days required to kill.	Square inches foliage consumed.
	July.														August.					September.		October.					
	15	16	17	18	19	20	21	22	23	24	25	26	27	29	2	4	8	14	25	2	13	3	18				
Arsenate of lead,[1] di., 1–55	3	2	7	1	4	3																			20	7	0.23
Arsenate of lead, tri., 1–42	2	4	1	3	4	2	2	2																	20	9	.28
Arsenate of lead, di. and tri., 1–50	1	1	3	1	2	6	6																		20	8	1.40
Arsenate of lead, triplumbic, com. (1), 2–50	1	1	1	2	3	1	0	2	2	3	1	1													[2] 18	13	.70
Arsenate of lead, com. (2), 2–50	5	7	5	1	1	1																			20	7	.37
Arsenate of lead, com. (3), 2–50	3	6	6	3	1	1																			20	7	.39
Arsenate of calcium, c. p. (powder), 1–52	4	2	3	4	1	2	1	1																	[2] 18	9	.02
Arsenate of iron, c. p. (powder), 2–50	4	7	2	0	1	1	1																		[2] 16	8	.17
Arsenate of iron, h. m., $1\frac{6}{10}$–50	9	3	3	0	2	0	1	2																	20	9	.40
Arsenate of zinc, c. p. (powder), 1–46	1	4	4	3	0	2	2	3	1																20	10	.46
Arsenate of zinc, h. m., $\frac{8}{10}$–50	0	6	9	4	1																				20	6	.12
Arsenic sulphid, 1–54	0	0	2	0	0	3	0	0	0	0	0	1	1	9	3										[2] 19	19	2.80
Arsenic tersulphid, ½–50	1	5	8	4																					[2] 18	5	.16
Arsenic trioxid, ½–56	1	3	7	2	3	4																			20	7	.25
Arsenite of lime, 2 pts.–50	2	4	3	1	1	3	4	1	0	1															20	11	.33
Arsenite of zinc[1] (1), ½–43	6	12	1	1																					20	5	.12
Arsenite of zinc (2), 1½–50	6	0	3	2	2	2	0	2	1	1	1														20	12	.60
Arsenite of zinc (3), ¾–50	2	3	0	1	1	0	0	3	6	2															[2] 18	11	.93
Arsenite of zinc (4), ¾–50	8	8	4																						20	4	.07
Barium chlorid, 6–50	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	4	[2] 10	97	67.75
Barium sulphate, 6–50	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	3		4	[2] 8	82	99.86
Calcium chlorid, 6–50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	3	0	1	7	[2] 7	97	62.00
Copper oxid, 6–50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	1	0	2	8	[2] 9	97	176.00
Lead acetate, 6–50	0	0	0	0	0	0	0	0	0	0	0	2	1	1	1	0	0	0	2	0	1	0	2	4	[2] 9	97	122.00
Lead carbonate, 6–50	0	1	0	0	1	2	2	0	0	0	0	0	0	0	2	0	0	1	1	1	0	0		6	[2] 11	82	80.00
Lead chromate, 4–50	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3	1	7	3						[2] 16	43	3.72
Lead oxid, 6–50	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2			5	[2] 6	62	81.96
Lead peroxid, 6–50	0	2	0	0	0	0	0	1	0	1	1	1	1	1	0	0	0	0	0	1	1	1			[2] 10	82	18.90
Mercury bichlorid, ¾–50	0	2	1	2	2	1	3	6																	[2] 17	9	.27
Zinc chlorid, 3–50	1	0	0	0	1	1	0	0	0	0	0	0	1	2	1	4	3								[2] 14	26	3.73
Zinc oxid, 6–50	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	8	1	2				[2] 16	62	9.48
Zinc sulphate, 6–50	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	4	5	0	0	1		[2] 14	97	12.37
Check (unsprayed) 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0		9	[2] 4	82	155.55
Check (unsprayed) 2	2	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0		12	[2] 7	82	131.38
Check (unsprayed) 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0		9	[2] 3	82	192.00

[1] Arsenate of lead, di.=diplumbic powder; tri.=triplumbic powder; di. and tri.=mixture of diplumbic and triplumbic powder; com. (1), (2), (3)=commercial paste. Arsenite of zinc, (1)=chemically pure; (2)=paste, commercial; (3)=powder, commercial; (4)=powder, commercial; c. p.=chemically pure; h. m.=homemade.

[2] Remainder escaped.

As will be noted, while the triplumbic arsenate of lead was very effective against the larvæ, it was somewhat slower in its killing effect than the diplumbic and the mixture of diplumbic and triplumbic arsenate of lead. This held true in the other experiments that follow. Of the three commercial arsenates of lead, commercial (1), which consisted of the triplumbic form, required a greater length of time to kill the larvæ than was required by the other two commercial brands, which consisted mainly of the diplumbic form.

Arsenate of iron, both chemically pure and homemade, was used at double strength, owing to indications of slow killing effect in previous tests. At this strength it was somewhat slower than many of the other arsenicals. Like results will be noted in later experiments with this material.

The arsenates of zinc were effective and seemed to be safe to use on the foliage.

Arsenic sulphid, arsenic tersulphid, arsenic trioxid, arsenite of lime, and the arsenites of zinc were effective, but burned the foliage more or less seriously.

Mercury bichlorid and zinc chlorid, while effective, were very injurious to the foliage.

All the other compounds were ineffective.

Experiment II.

COMPARISON OF THE KILLING EFFECT OF VARIOUS ARSENICALS AND DOUBTFUL STOMACH POISONS COMBINED WITH LIME-SULPHUR SOLUTION ON LARVÆ OF THE FALL WEB-WORM.

In Table II are given the results of using lime-sulphur at the rate of 1½ gallons to 50 gallons of spray in combination with all the materials used. Little difference was noted from the use of these combinations of lime-sulphur with the arsenicals. However, in case of the materials which had no effect on the larvæ when used alone a marked difference was evident from the addition of lime-sulphur. In all cases the larvæ were killed, the length of time of killing varying considerably with the material used. The difference no doubt was largely due to the difference in chemical reaction between the material and the lime-sulphur. Lime-sulphur alone killed the 20 larvæ in 15 days with only 0.73 square inches of foliage consumed. In Table II are shown the results.

TABLE II.—*Tests of the killing effect of various arsenicals and doubtful stomach poisons combined with lime-sulphur on the fall webworm.*

[Experiment started July 20, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Name and dilution.	Dates of examination and number of larvæ dying in each lot.																									Total number dead.	Number days required to kill.	Square inches foliage consumed.
	July.									August.													September.					
	22	23	24	25	26	27	28	29	31	2	4	6	8	10	12	14	16	19	21	24	26	28	2	19	30			
Lime-sulphur, 1½-50, combined with the following:																												
Arsenate of lead,[1] di., 1-55	0	1	1	0	2	4	1	4	5	2																20	13	0.16
Arsenate of lead,[1] tri., 1-42	0	0	0	1	0	3	0	3	6	1	2															[2]16	15	2.25
Arsenate of lead,[1] di. and tri., 1-50	2	1	1	4	4	7	1																			20	8	.15
Arsenate of lead,[1] triplumbic, com. (1), 2-50	1	2	0	1	0	5	0	5	4	1																[2]19	13	.44
Arsenate of lead,[1] com. (2), 2-50	4	3	3	4	2	4																				20	7	.02
Arsenate of lead,[1] com. (3), 2-50	0	0	1	7	10	2																				20	7	.12
Arsenate of calcium, c. p.[1] (powder), 1-50	0	1	1	4	3	5	3	3																		20	9	.13
Arsenate of iron, c. p.[1] (powder), 1-50	0	0	2	3	3	8	1	1																		[2]18	9	.39
Arsenate of iron, h. m.,[1] $\frac{8}{10}$-50	0	1	5	6	2	1	0	1	1	2	1															20	15	1.22
Arsenate of zinc, c. p.[1] (powder), 1-46	0	0	1	7	2	6	4																			20	8	.15
Arsenate of zinc, h. m.,[1] $\frac{8}{10}$-50	2	1	4	1	6	4	2																			20	8	.33
Arsenic sulphid, 1-54	1	1	0	5	9	0	3	1																		20	9	.10
Arsenic tersulphid, ½-50	0	0	3	5	4	3	0	2																		[2]17	9	.007
Arsenic trioxid, ¼-56	0	0	2	14	3	1																				20	7	.06
Arsenite of lime,[1] h. m., 2 pts-50	1	1	2	2	1	1	4	5	3																	20	11	.22
Arsenite of zinc[1] (1), ½-43	0	0	3	5	5	6	1																			20	8	.12
Arsenite of zinc[1] (2), 1½-50	0	1	8	3	5	2																				[2]19	7	.06
Arsenite of zinc[1] (3), ¾-50	0	0	1	1	2	6	9	1																		20	9	.25
Arsenite of zinc[1] (4), ¾-50	0	0	2	3	3	3	2	3	2	2																20	13	.26
Barium chlorid, 6-50	0	0	0	1	0	0	0	0	0	5	3	2	5	3	1											20	23	2.52
Barium sulphate, 6-50	0	0	0	0	0	2	2	1	5	3	0	1	3	1	0	2										20	25	2.60
Calcium chlorid, 6-50	0	0	0	0	1	3	1	6	1	3	1	3	1													20	19	2.48
Copper oxid, 6-50	0	0	0	1	4	4	3	6	2																	20	11	.68
Lead acetate, 6-50	0	0	1	2	4	3	1	0	1	1	0	0	1	1	2											[2]17	23	1.33
Lead carbonate, 6-50	0	1	0	2	2	2	4	2	2	1	0	0	0	0	1	0	0	0	0	2						[2]19	35	3.12
Lead chromate, 6-50	0	0	0	0	0	7	3	7	3																	20	11	.50
Lead oxid, 6-50	0	0	0	0	1	1	0	3	3	2	1	0	1	0	2	2	2	0	0	0	1	0	1			20	44	9.52
Lead peroxid, 6-50	0	0	0	0	0	0	1	2	1	0	1	2	2	4	1	3	3									20	27	14.70
Mercury bichlorid, ¾-50	0	0	0	0	1	1	3	3	3	3	0	0	2	0	0	0	0	3	0	0	1					20	37	5.41
Zinc chlorid, 3-50	0	0	0	0	10	8	2																			20	9	.62
Zinc oxid, 6-50	0	0	0	0	1	3	3	2	2	0	1	0	2	2	0	3	0	0	0	1						20	35	7.00
Zinc sulphate, 6-50	0	0	0	0	0	3	0	0	2	0	0	0	1	2	1	1	1	1	3	1	0	0	2			[2]18	44	8.63
Lime-sulphur, 1½-50	0	0	0	0	4	3	3	4	4	1	1															20	15	.73
Check (unsprayed) (1)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	4	72	243.20
Check (unsprayed) (2)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1			2	61	162.00

[1] Arsenate of lead, di.=diplumbic powder; tri.=triplumbic powder; di. and tri.=mixture of diplumbic and triplumbic powders; com. (1), (2), and (3)=commercial paste. Arsenite of zinc, (1)=chemically pure; (2)=paste, commercial; (3)=powder, commercial; (4)=powder, commercial. c. p.=chemically pure; h. m.=homemade.

[2] Remainder escaped.

Experiment III.

COMPARISON OF THE KILLING EFFECT OF VARIOUS ARSENICALS ON LARVÆ OF THE FALL WEBWORM.

In this experiment the same arsenicals were used as in Experiment I, all the other materials being omitted. However, since half-grown larvæ were used the strength of the materials was doubled. The results are shown in Table III.

Table III.—*Tests of the killing effect of various arsenicals on the fall webworm. Larvæ half grown.*

[Experiment started July 24, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Name and dilution.	Dates of examination and number of larvæ dying in each lot.									Total number dead.	Number days required to kill.	Square inches foliage consumed.
	July.					August.						
	26	27	28	29	31	2	4	7	12			
Arsenate of lead, di., 2–55	0	0	1	4	15	....	....	....	....	20	7	1.22
Arsenate of lead, tri., 2–42	0	0	0	1	1	7	8	3	....	20	14	.60
Arsenate of lead, di. and tri., 2–50	0	2	2	3	9	4	....	....	....	20	9	.43
Arsenate of lead, triplumbic, com. (1), 4–50	0	1	2	1	12	2	1	1	....	20	14	.84
Arsenate of lead, com. (2), 4–50	1	0	3	6	10	....	....	....	....	20	7	.94
Arsenate of lead, com. (3), 4–50	0	0	5	10	5	....	....	....	....	20	7	.37
Arsenate of calcium, c. p. (powder), 2–50	0	0	1	0	10	4	5	....	....	20	11	1.15
Arsenate of iron, c. p. (powder), 4–50	0	0	0	1	1	3	1	4	2	12	19	(2)
Arsenate of iron, h. m., $3\frac{2}{10}$–50	0	0	1	1	1	1	1	2	2	9	19	(2)
Arsenate of zinc, c. p. (powder), 2–46	4	0	0	5	11	....	....	....	....	20	7	2.03
Arsenate of zinc, h. m., $1\frac{6}{10}$–50	0	0	1	7	7	2	1	2	....	20	14	.87
Arsenic sulphid, 2–54	3	0	2	7	8	....	....	....	....	20	7	.95
Arsenic tersulphid, 1–50	4	1	3	5	3	4	....	....	....	20	9	.19
Arsenic trioxid, 1–56	5	6	4	0	3	1	....	....	....	[1] 19	9	.06
Arsenite of lime, 4 pts.–50	1	0	3	10	6	....	....	....	....	20	7	.56
Arsenite of zinc, c. p. (1), 2–43	3	0	2	9	4	....	....	....	....	[1] 18	7	.15
Arsenite of zinc, com. (2), 3–50	0	0	3	1	12	4	....	....	....	20	9	1.08
Arsenite of zinc, com. (3), $1\frac{1}{2}$–50	0	1	2	5	5	7	....	....	....	20	9	.94
Arsenite of zinc, com. (4), $1\frac{1}{2}$–50	0	0	1	3	9	6	....	....	....	[1] 19	9	.41
Check (unsprayed) (1)	0	0	0	0	0	0	0	0	0	0	19	(2)
Check (unsprayed) (2)	0	0	0	0	0	0	0	0	0	0	19	(2)

[1] Remainder escaped. [2] Not measured.

The results of these tests agree very well with the results obtained from Experiment I. The experiment was discontinued August 12, when all the larvæ were dead except in the case of arsenate of iron, chemically pure, where 8 larvæ still remained living, and arsenate of iron, homemade, where 11 remained living. All the larvæ on the unsprayed lots were alive at the time the experiment was closed.

Experiment IV.

FIELD TESTS OF VARIOUS ARSENICALS AGAINST THE CODLING MOTH IN MICHIGAN, 1912.

Several arsenicals were tested in comparison with arsenate of lead against the codling moth in Mr. J. T. Beckwith's apple orchard in the vicinity of Benton Harbor. The trees were of the Ben Davis variety and about 35 years of age. The plats consisted of from 4 to 12 trees, and the fruit was counted from 3 trees of each plat. The extent of foliage injury from the various sprays was also noted. The homemade preparations were prepared and diluted as given on page 2. The results against the codling moth are shown in Table IV.

TABLE IV.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test, Benton Harbor, Mich., 1912.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution	1	64	4,430	4,494	98.58
		2	14	1,542	1,556	99.10
		3	9	879	888	98.98
	Plat total	......	**87**	**6,851**	**6,938**	**98.74**
II	Arsenate of lead (paste) commercial No. 1 (triplumbic), 2 pounds to 50 gallons lime-sulphur solution	1	33	874	907	96.36
		2	84	1,727	1,811	95.36
		3	44	1,115	1,159	96.20
	Plat total	......	**161**	**3,716**	**3,877**	**95.85**
III	Arsenite of zinc (powder), ¾ pound to 50 gallons lime-sulphur solution	1	4	734	738	99.46
		2	20	1,110	1,130	98.23
		3	15	744	759	98.02
	Plat total	......	**39**	**2,588**	**2,627**	**98.52**
IV	Arsenite of zinc (paste), 1½ pounds to 50 gallons lime-sulphur solution	1	19	1,387	1,406	98.65
		2	27	2,638	2,665	98.99
		3	7	486	493	98.58
	Plat total	......	**53**	**4,511**	**4,564**	**98.83**
V	Arsenite of lime, homemade, 2 pints to 50 gallons lime-sulphur solution	1	32	680	712	95.50
		2	75	1,282	1,357	94.47
		3	52	1,201	1,253	95.85
	Plat total	......	**159**	**3,163**	**3,322**	**95.21**
VI	Arsenate of zinc, homemade, at rate of 0.8 pound sodium arsenate to 50 gallons lime-sulphur solution	1	80	1,030	1,110	92.79
		2	261	1,597	1,858	85.95
		3	108	1,257	1,365	92.09
	Plat total	......	**449**	**3,884**	**4,333**	**89.63**
VII	Arsenate of iron, c. p. (powder), ½ pound to 50 gallons lime-sulphur solution	1	174	942	1,116	84.41
		2	413	1,176	1,589	74.01
		3	254	1,228	1,482	82.86
	Plat total	......	**841**	**3,346**	**4,187**	**79.91**
VIII	Arsenate of iron, homemade, at rate of 0.8 pound sodium arsenate to 50 gallons lime-sulphur solution	1	228	800	1,028	77.82
		2	205	970	1,175	82.55
		3	537	1,466	2,003	73.19
	Plat total	......	**970**	**3,236**	**4,206**	**76.93**
IX	Arsenate of calcium, c. p. (powder), ½ pound to 50 gallons lime-sulphur solution	1	205	1,672	1,877	89.03
		2	95	529	624	84.77
		3	160	847	1,007	84.11
	Plat total	......	**460**	**3,048**	**3,508**	**86.88**
X	Check (unsprayed)	1	257	231	488	47.33
		2	487	274	761	36.01
		3	744	445	1,189	37.43
	Plat total	......	**1,488**	**950**	**2,438**	**38.96**

Arsenate of lead held the codling moth to 98.74 per cent of fruit free from worms, with no foliage injury resulting. Commercial arsenate of lead No. 1 (triplumbic) produced 95.85 per cent free from this insect, and the foliage was not injured. Arsenite of zinc powder and arsenite of zinc paste were as effective against the codling moth as arsenate of lead, but considerable foliage injury resulted from their use, about 50 per cent of the leaves being burned on these plats.

Arsenate of zinc, homemade, was effective, but fell somewhat below arsenate of lead in its efficiency. The foliage was not in the least injured from the use of this material.

Arsenates of iron, chemically pure and homemade, did not burn the foliage, but they were only moderately effective against the codling moth. As will be noted from the laboratory feeding tests with this material, its killing effect is slow.

Arsenate of calcium, chemically pure, 0.5 pound to 50 gallons, held the codling moth to 86.88 per cent of fruit free from injury. This fell somewhat below the efficiency of the standard arsenate of lead. However, the use of a slightly increased strength of this material would no doubt have been as effective as arsenate of lead, since it proved to be an effective poison in the laboratory feeding tests. Absolutely no burning resulted from its use, and its sticking qualities were excellent, as was indicated by the abundance of the material that could still be found on the foliage after several hard rains.

Only 38.96 per cent of the fruit from the three trees of the unsprayed plat was free from codling-moth injury.

Experiment V.

FOLIAGE INJURY TESTS OF VARIOUS ARSENICALS AND LIME-SULPHUR SOLUTION ON FOLIAGE OF PEACH AND BEAN.

A bean patch was planted in the laboratory yard, August 1, for the purpose of testing the burning effect of the various poisons used in the feeding tests. The leaves were sprayed with a large atomizer August 31. One row containing about 30 plants was used for each poison, one-third of the row being sprayed with the poison alone, one-third with the poison combined with lime at the strength of 2 pounds to 50 gallons of spray, and the remaining third with the poison combined with lime-sulphur, 1½ gallons to 50 gallons of spray. The spray was prevented from blowing to other parts of the row and to other rows by a canvas frame which was placed around the part being sprayed.

An experiment was also conducted on peach foliage on several trees in the laboratory yard. The poisons were used alone in all cases and were applied by means of an atomizer, using one peach limb for each poison. The spray was prevented from reaching other parts of the tree by the use of a funnel-shaped canvas protector that was placed over the limb being sprayed.

The results of both bean and peach foliage tests are shown in Table V.

TABLE V.—*Tests of the effect of various arsenicals on foliage of bean and peach.*

[Experiment started Aug. 31, 1912, Benton Harbor, Mich. Foliage examined for two weeks.]

INJURY TO BEAN FOLIAGE.

Name and dilution.	Poison used alone.	Poison combined with lime, 2 to 50.	Poison combined with lime-sulphur, 1½ to 50.
Arsenate of lead, di. (powder), 1–50	No burning	No burning	No burning.
Arsenate of lead, tri. (powder), 1–50	do	do	Do.
Arsenate of lead, di. and tri. (powder), 1–50	do	do	Do.
Arsenate of lead, tri. com. paste (1), 2–50	do	do	Do.
Arsenate of lead, tri. com. paste (2), 2–50	Moderate burning	do	Do.
Arsenate of lead, tri. com. paste (3), 2–50	No burning	do	Do.
Arsenate of calcium, c. p. (powder), 1–50	do	do	Do.
Arsenate of iron, c. p. (powder), 2–50	do	do	Do.
Arsenate of iron, h. m., 8/10–50	do	do	Do.
Arsenate of zinc, c. p. (powder), 1–50	do	do	Do.
Arsenate of zinc, h. m., 8/10–50	do	do	Do.
Arsenic sulphid, 1–50	Severe burning	Severe burning	Severe burning.
Arsenic tersulphid, ½–50	do	do	Do.
Arsenic trioxid, ½–50	do	Slight burning	Do.
Arsenite of lime, h. m., 2 pts.–50	Moderate burning	No burning	Moderate burning.
Arsenite of zinc, powder (1) c. p., 1–50	Severe burning	do	Severe burning.
Arsenite of zinc (2), com. powder, ¾–50	Moderate burning	do	Moderate burning.
Arsenite of zinc (3), com. paste, 1½–50	do	do	Do.
Arsenite of zinc (4), com. powder, ¾–50	do	do	Do.
Paris green, ½–50	do	Moderate burning	Do.
Lime-sulphur, 1½–50	No burning		

INJURY TO PEACH FOLIAGE.

Name and dilution.	Poison used alone.
Aresenate of lead, di. (powder), 1–50	Very slight burning.
Arsenate of lead, tri. (powder), 1–50	No burning.
Arsenate of lead, di. and tri. (powder), 1–50	Slight burning.
Arsenate of lead, tri. com. paste (1), 2–50	No burning.
Arsenate of lead, tri. com. paste (2), 2–50	Severe burning.
Arsenate of lead, tri. com. paste (3), 2–50	Very slight burning.
Arsenate of calcium, c. p. (powder), 1–50	Moderate burning.
Arsenate of iron, c. p. (powder), 2–50	No burning.
Arsenate of iron, h. m., 8/10–50	Do.
Arsenate of zinc, c. p. (powder), 1–50	Severe burning.
Arsenate of zinc, h. m., 8/10–50	Very slight burning.
Arsenic sulphid, 1–50	Severe burning.
Arsenic tersulphid, ½–50	Do.
Arsenic trioxid, ½–50	Do.
Arsenite of lime, h. m., 2 pts.–50	Do.
Arsenite of zinc, powder (1), c. p., 1–50	Do.
Arsenite of zinc (2), com. powder, ¾–50	Do.
Arsenite of zinc (3), com. paste, 1½–50	Do.
Arsenite of zinc (4), com. powder, ¾–50	Do.
Paris green, ½–50	Do.
Lime-sulphur, 1½–50	

Of the arsenates of lead, the diplumbic form had no burning effect on bean foliage and burned peach foliage very slightly. Arsenate of lead, consisting of a mixture of the diplumbic and triplumbic forms, burned peach foliage slightly, but no injury resulted on bean foliage. The commercial No. 1, consisting of the triplumbic form of arsenate of lead, did not injure peach or bean foliage. The commercial (2) burned the peach so badly that all the leaves were shed, and produced moderate burning on the bean, about 25 per cent of the leaves being shed, but no burning where it was combined with lime or lime-sulphur. The commercial (3) produced no burning on bean foliage and very slight burning on peach foliage.

Arsenate of calcium, c. p., caused about 15 per cent of the leaves to drop on peach, but had no burning effect on bean foliage.

The arsenates of iron, chemically pure and homemade, did not burn either bean or peach foliage.

Arsenate of zinc, c. p., did not burn bean foliage, but seriously injured peach foliage, causing complete defoliation. The homemade form of arsenate of zinc produced very slight burning on peach and no burning on bean foliage.

Arsenic sulphid produced severe burning in all tests.

Arsenic tersulphid produced the same results as arsenic sulphid.

Arsenic trioxid burned severely in all cases except when combined with lime, in which case the burning was slightly less.

Arsenite of lime, homemade, burned the bean foliage moderately when used alone and in combination with lime-sulphur. However, no burning resulted when extra lime was added. The peach foliage was severely burned by this material, causing all the leaves to drop.

Arsenite of zinc (1), chemically pure, burned severely in all cases except where lime was used, in which case no burning resulted.

Arsenite of zinc powder, commercial (2), burned moderately on beans except where lime was added, in which case no burning resulted. It caused all of the peach leaves to drop. Arsenite of zinc, commercial (3) and commercial (4), gave the same results.

Paris green produced moderate burning in all the tests on bean foliage and burned all the leaves off the peach.

EXPERIMENTS, 1913.

LABORATORY TESTS.

Several poisons, namely, arsenate of lead paste, commercial; two commercial brands of powdered arsenate of lead; arsenate of calcium, commercial; two forms of arsenate of calcium, homemade; arsenate of zinc, homemade, and arsenite of zinc, homemade, were tested against the larvæ of several different species of chewing insects.

The arsenates of lead and the arsenite of zinc were used at the strengths recommended by the manufacturers. Arsenate of calcium, commercial paste, was used at the rate of 1⅓ pounds to 50 gallons of water. Arsenate of zinc, homemade, was prepared and used as given on page 2. Arsenate of calcium (1) was prepared by dissolving 1 pound of sodium arsenate and 1 pound of calcium acetate each in 1 gallon of hot water and pouring them together slowly, at the same time stirring the solution vigorously. This was used at a strength equivalent to 0.8 pound of sodium arsenate to 50 gallons of water. Arsenate of calcium, homemade (2), was prepared from sodium arsenate and calcium chlorid, the method of procedure being the same as for arsenate of calcium, homemade (1), and was used at the same strength.

Lead chromate, commercial, was used at the rate of 8 pounds to 50 gallons. Lead chromate, homemade, was prepared by dissolving 2 ounces of lead nitrate in one lot of water and 1 ounce of potassium bichromate in another lot of water. The two solutions were then mixed, and a dense yellow precipitate of insoluble lead chromate was formed. The amount of lead chromate formed is 2 ounces, and the strengths at which the material was used in these experiments were based on the amount of lead chromate formed.

H. Maxwell-Lefroy and R. S. Finlow state the following in regard to the use of the above form of homemade lead chromate as an insecticide:[1]

> During this year we have applied this compound to a great variety of crops. We have sprayed them till every leaf was yellow. The poison has remained on for over three weeks, thickly on the leaves, which were uninjured. Sprayed on to crops attacked by caterpillars, the caterpillars are killed, and the results obtained have been excellent. We have used this at 1 pound in 32 gallons. At this strength it is entirely safe, poisons caterpillars, and acts as a very powerful deterrent. * * * Lead chromate has not the poisoning effect of Paris green, for instance, which can be applied at 1 pound in 200 gallons, but it has a poisoning effect comparable with that of lead arsenate, and is, in our experience, a perfect substitute.

As a result of this success with the use of this preparation as an insecticide in India, thorough tests were made with it in experiments conducted during the season of 1913.

Experiment VI.

ARSENATE OF LEAD VERSUS ARSENATE OF CALCIUM AGAINST LARVÆ OF THE TENT CATERPILLAR.

In this experiment arsenate of lead paste and the different forms of arsenate of calcium were tested in comparison against newly hatched larvæ of the tent caterpillar. The results of this test are shown in Table VI.

Arsenate of lead alone killed the 50 larvæ in each of the two lots in 5 days, with 0.04 square inch of foliage consumed. Combined with lime-sulphur it required 2 days longer to kill, but only 0.01 square inch of foliage was consumed.

Arsenate of calcium, homemade (1), prepared from sodium arsenate and calcium acetate, killed the larvæ in 5 to 7 days, with 0.05 and 0.06 square inch of foliage consumed when used alone, and in 5 days when combined with lime-sulphur, with 0.02 square inch of foliage consumed. Arsenate of calcium, homemade (2), gave practically the same results.

[1] Maxwell-Lefroy, H., and Finlow, R. S. Inquiry into the insecticidal action of some mineral and other compounds on caterpillars. *In* Memoirs Dept. Agr. India, Ent. Ser., v. 4, no. 5, p. 269–327, 1913.

TABLE VI.—*Tests of the killing effect on the tent caterpillar of arsenate of calcium, alone and combined with lime-sulphur, in comparison with arsenate of lead.*

[Experiment started May 17, 1913, Benton Harbor, Mich.; 50 larvæ in each lot.]

Dates of examination.	Check (unsprayed).		Larvæ dying in each lot.												
			Arsenate of lead, 2 to 50.			Arsenate of calcium (homemade, 1), 0.8 lb. to 50.			Arsenate of calcium (homemade, 2), 0.8 lb. to 50.			Arsenate of calcium (commercial paste), $1\frac{1}{3}$ to 50.		
			Alone.		With lime-sulphur, $1\frac{1}{2}$ to 50.	Alone.		With lime-sulphur, $1\frac{1}{2}$ to 50.	Alone.		With lime-sulphur, $1\frac{1}{2}$ to 50.	Alone.		With lime-sulphur, $1\frac{1}{2}$ to 50.
	Lot 1.	Lot 2.	Lot 3.	Lot 4.	Lot 5.	Lot 6.	Lot 7.	Lot 8.	Lot 9.	Lot 10.	Lot 11.	Lot 12.	Lot 13.	Lot 14.
May 20	1	1	42	45	16	36	38	27	30	33	20	35	43	28
May 22	2	1	8	5	27	12	12	23	18	17	20	15	7	18
May 24	1	0	.....	.....	7	2	.....	.....	2	.....	10	.....	.....	4
May 31	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total number dead	4	2	50	50	50	50	50	50	50	50	50	50	50	50
Days required to kill	.....	.....	5	5	7	7	5	5	7	5	7	5	5	7
Square inches foliage consumed	8.10	6.75	0.04	0.04	0.01	0.05	0.06	0.02	0.04	0.06	0.02	0.06	0.05	0.03

Arsenate of calcium, commercial (paste), used at the rate of $1\frac{1}{3}$ pounds to 50 gallons killed all the larvæ in 5 days with 0.05 and 0.06 square inch of foliage consumed. The same preparation combined with lime-sulphur killed in 7 days with 0.03 square inch of foliage consumed.

It will be noted that when lime-sulphur was used with the poison, less foliage was consumed.

EXPERIMENT VII.

LEAD CHROMATE VERSUS ARSENATE OF LEAD AGAINST THE LARVÆ OF FOUR SPECIES OF INSECTS.

Experiments were conducted with lead chromate, commercial and homemade, used at various strengths in comparison with arsenate of lead used at the rate of 2 pounds to 50 gallons of water, against four species of insects, *Eriocampoides cerasi* Peck, *Hyphantria cunea*, *Halisidota caryae* Harris, and *Datana ministra* Drury. The results of these experiments are given in Table VII.

Neither the commercial nor homemade lead chromate was very effective against the pear slug (*Eriocampoides cerasi*), 6 larvæ living through to pupation in each case, and almost as much foliage was consumed as on one of the checks. Arsenate of lead killed 8 of the larvæ in 3 days. The other 2 larvæ escaped. Nine of the larvæ pupated in each of the two unsprayed lots.

TABLE VII.—*Tests of the killing effect on four species of insects of commercial and homemade lead chromate in comparison with arsenate of lead.*

[Benton Harbor, Mich., 1913.]

Name of insect.	Number of larvæ.	Name of material and dilution.	Date experiment started.	Date experiment closed.	Number of observations.	Total larvæ dead.	Number days required to kill.	Square inches foliage consumed.
Eriocampoides cerasi	10	Check (unsprayed)	July 2	July 7	5	[1] 1		9.64
	10	do	do	do	5	[1] 1		4.36
	10	Arsenate of lead, commercial, 2–50.	do	July 5	3	[2] 8	3	0.25
	10	Lead chromate, commercial, 2–50.	do	July 7	5	[1] 4		3.48
	10	Lead chromate, homemade, $\frac{3}{4}$–50.	do	do	5	[1] 4		3.39
Hyphantria cunea	20	Check (unsprayed)	July 14	July 31	9	4		41.00
	20	do	do	do	9	4		37.00
	20	Arsenate of lead, commercial, 2–50.	do	July 18	2	20	4	.08
	20	do	do	do	2	20	4	.14
	20	Lead chromate, commercial, 8–50.	do	July 21	4	20	7	.96
	20	do	do	do	4	20	7	.72
	20	Lead chromate, homemade, 1$\frac{1}{2}$–50.	do	July 23	5	20	9	1.04
	20	do	do	July 21	4	20	7	.88
Halisidota caryæ	20	Check (unsprayed)	do	Aug. 1	9	1		3.50
	20	do	do	do	9	1		2.20
	20	Arsenate of lead, commercial, 2–50.	do	July 18	2	20	4	.30
	20	do	do	do	2	20	4	.50
	20	Lead chromate, commercial, 2–50.	do	Aug. 1	9	1		3.25
	20	do	do	do	9	3		3.50
	20	Lead chromate, homemade, $\frac{3}{4}$–50.	do	do	9	1		1.50
	20	do	do	do	9	0		1.60
Datana ministra	20	Check (unsprayed)	Aug. 8	Aug. 14	6	1		
	20	Arsenate of lead, commercial, 2–50.	do	Aug. 10	2	20	2	
	20	Lead chromate, commercial, 8–50.	do	do	2	20	2	
	20	Lead chromate, homemade, $\frac{3}{4}$–50.	do	Aug. 14	6	20	6	
	20	Lead chromate, homemade, 1$\frac{1}{2}$–50.	do	Aug. 13	5	20	5	
	20	Lead chromate, homemade, 3–50.	do	Aug. 10	2	20	2	

[1] Remainder pupated. [2] Remainder escaped.

Against the fall webworm (*Hyphantria cunea*) lead chromate, used at the rate of 8 pounds to 50 gallons of water, was effective, although 3 more days were required to kill in this case than in the case of arsenate of lead used at the rate of 2 pounds to 50 gallons of water. The strength of lead chromate in this case is four times greater than was used against the pear slug. Lead chromate, homemade, was used at the rate of 1$\frac{1}{2}$ pounds to 50 gallons of water, twice the strength that was used against the pear slug. All the larvæ were killed in 7 to 9 days, which was considerably slower than with arsenate of lead, and considerably more foliage was consumed. Four of the larvæ were dead in each lot of the checks at the end of the experiment, which was closed July 31.

The experiment against *Halisidota caryae* ran for 18 days, at the end of which time the lead chromate, commercial and homemade, used at the weaker strengths, apparently had no effect on the larvæ. The arsenate of lead killed all the larvæ in 4 days.

For the *Datana ministra*, the commercial lead chromate was used at the rate of 8 pounds to 50 gallons of water, and at this strength the killing effect of the material compared favorably with that of arsenate of lead, 2 pounds to 50 gallons. The lead chromate, homemade, was used at three strengths—$\frac{3}{4}$, $1\frac{1}{2}$, and 3 pounds to 50 gallons of water. The weakest strength killed all the larvæ in 6 days, the next stronger in 5 days. Only one larva had died in the unsprayed lot at the time the experiment was closed, August 14.

Experiment VIII.

COMPARISON OF THE KILLING EFFECT OF ARSENATE OF LEAD, ARSENATE OF CALCIUM, ARSENATE OF ZINC, ARSENITE OF ZINC, AND LEAD CHROMATE ON LARVÆ OF THE FALL WEBWORM.

Different forms of arsenate of lead, arsenate of calcium, and lead chromate were tested against the larvæ of the fall webworm (*Hyphantria cunea*). Arsenate of zinc and arsenite of zinc were also included in this test, as shown in Table VIII.

Table VIII.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started July 23, 1913, Benton Harbor, Mich.; 20 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.												Total number dead.	Number days required to kill.	Square inches foliage consumed.
		July.								August.						
		24	25	26	27	28	29	30	31	1	2	3	4			
1	Arsenate of lead paste, commercial, 2–50	0	0	0	0	4	9	7	....	....	....	....	....	20	7	0.42
2	.....do	0	1	1	1	10	6	1	....	....	....	....	....	20	7	.24
3	Arsenate of lead powder, commercial (1), 1–50	0	0	0	0	4	9	7	....	....	....	....	....	20	7	.41
4	.....do	0	0	2	2	10	4	2	....	....	....	....	....	20	7	.22
5	Arsenate of lead powder, commercial (2), 1–50	0	0	1	5	7	7	....	....	....	....	....	....	20	6	.13
6	.....do	0	0	2	1	6	9	2	....	....	....	....	....	20	7	.24
7	Arsenate of calcium paste, commercial, $1\frac{1}{3}$–50	0	1	0	1	10	1	5	2	....	....	....	....	20	8	.75
8	.....do	0	1	1	2	5	3	5	3	....	....	....	....	20	8	.88
9	Arsenate of calcium, homemade (1), $\frac{8}{10}$–50	0	0	0	7	11	2	....	....	....	....	....	....	20	6	.15
10	.....do	0	0	1	3	15	1	....	....	....	....	....	....	20	6	.17
11	Arsenate of calcium, homemade (2), $\frac{8}{10}$–50	0	0	2	2	12	2	2	....	....	....	....	....	20	7	.19
12	.....do	0	0	1	2	12	3	2	....	....	....	....	....	20	7	.12
13	Arsenate of zinc, homemade, $\frac{8}{10}$–50	0	0	0	1	18	1	....	....	....	....	....	....	20	6	.29
14	.....do	0	0	0	1	16	3	....	....	....	....	....	....	20	6	.20
15	Arsenite of zinc powder, commercial, $\frac{3}{4}$–50	0	1	2	7	3	2	4	1	....	....	....	....	20	8	.50
16	.....do	0	1	0	2	8	5	1	3	....	....	....	....	20	8	.79
17	Lead chromate powder, commercial, 8–50	0	0	0	0	1	9	8	2	....	....	....	....	20	8	.84
18	.....do	0	0	0	0	0	5	5	7	1	1	1	....	20	11	2.01
19	Lead chromate, homemade, $1\frac{1}{2}$–50	0	0	0	0	1	6	8	1	2	2	....	....	20	10	1.70
20	.....do	0	0	0	0	0	4	6	1	3	4	1	1	20	12	2.09
21	Check (unsprayed)	0	0	0	0	0	0	0	1	0	0	2	0	3	......	20.17
22	.....do	0	0	0	0	0	0	0	0	0	0	1	0	1	......	20.56

Seven days were required to kill the 20 larvæ by arsenate of lead paste, and the two powder forms of arsenate of lead gave almost identical results. Arsenate of calcium, commercial, was one day slower in killing, and slightly more foliage was consumed where this material was used. The two forms of arsenate of calcium, homemade, killed in 6 and 7 days, comparing favorably with the arsenates of lead both in the length of time required to kill and in the amount of foliage consumed. Arsenate of zinc, homemade, killed in 6 days, with 0.20 to 0.29 square inch of foliage consumed. Arsenite of zinc, commercial, required 8 days to kill all the larvæ and 0.79 to 0.84 square inch of foliage was consumed. Lead chromate used at increased strengths was again slow in its killing effect, and more foliage was consumed than in the case of the arsenates. Three larvæ in one lot and one larva in the other lot of unsprayed were dead at the time the experiment was closed August 4. On the two checks 20.17 and 20.56 square inches of foliage were consumed, respectively.

Experiment IX.

COMPARISON OF THE KILLING EFFECT OF ARSENATE OF LEAD, ARSENATE OF CALCIUM, ARSENATE OF ZINC, ARSENITE OF ZINC, AND LEAD CHROMATE ON LARVÆ OF THE TUSSOCK MOTH.

Three forms of arsenate of lead, three forms of arsenate of calcium, lead chromate (commercial), arsenate of zinc, and arsenite of zinc were tested against larvæ of the tussock moth (*Hemerocampa leucostigma* S. and A.). The experiment was started June 26 and closed July 6, when all the larvæ were dead except in the unsprayed lots. Table IX gives the results of this test.

The three forms of arsenate of lead killed in 4 days, except in one lot of the paste form which required 6 days to kill; the amount of foliage consumed for all the forms varying from 0.01 to 0.08 square inch. Arsenate of calcium, commercial, required on an average more than twice as long to kill as required by arsenate of lead, and considerably more foliage was consumed. The two forms of arsenate of calcium, homemade, killed in slightly less time than was required by the commercial form. Lead chromate, commercial, used at the strength of 8 pounds to 50 gallons of water killed in 6 to 8 days, which was a longer time than required by the ordinary strength of arsenate of lead. Arsenate of zinc, homemade, and arsenite of zinc, commercial, were slower in their killing effect on this insect than was arsenate of lead. Three larvæ were dead in each of two lots of the unsprayed and four dead in the remaining lot, and 5.55 to 7.20 square inches of foliage had been consumed at the time the experiment was closed.

TABLE IX.—*Tests of the killing effect of various poisons on the tussock moth.*

[Experiment started June 26, 1913, Benton Harbor, Mich.; 25 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and larvæ dying in each lot. June. 28	June. 30	July. 2	July. 4	July. 6	Total number dead.	Number days required to kill.	Square inches foliage consumed.
1	Arsenate of lead paste, commercial, 2–50	13	12	....	....	....	25	4	0.06
2	.....do	15	10	....	....	....	25	4	.01
3	.....do	11	11	3	....	....	25	6	.08
4	Arsenate of lead powder, commercial (1), 1–50	13	12	....	....	....	25	4	.01
5	.....do	7	18	....	....	....	25	4	.05
6	.....do	18	7	....	....	....	25	4	.02
7	Arsenate of lead powder, commercial (2), 1–50	10	15	....	....	....	25	4	.07
8	.....do	16	9	....	....	....	25	4	.04
9	.....do	17	8	....	....	....	25	4	.02
10	Arsenate of calcium paste, commercial, 1⅓–50	4	11	1	5	4	25	10	.50
11	.....do	2	3	7	13	....	25	8	.68
12	.....do	5	8	10	2	....	25	8	.42
13	Arsenate of calcium, homemade (1), 0.8–50	9	7	4	2	3	25	10	.20
14	.....do	10	7	4	4	....	25	8	.38
15	.....do	6	15	4	....	....	25	6	.15
16	Arsenate of calcium, homemade (2), 0.8–50	10	6	1	0	5	25	10	.10
17	.....do	4	17	3	1	....	25	8	.23
18	.....do	17	7	1	....	....	25	6	.06
19	Lead chromate, commercial, 8–50	0	9	16	....	....	25	6	.55
20	.....do	0	6	16	3	....	25	8	.20
21	.....do	0	5	20	....	....	25	6	.18
22	Arsenate of zinc, homemade, 0.8–50	10	10	1	4	....	25	8	.46
23	.....do	12	9	1	3	....	25	8	.38
24	.....do	5	15	0	5	....	25	8	.62
25	Arsenite of zinc powder, commercial, ¾–50	8	15	0	1	1	25	10	.60
26	.....do	6	9	8	2	....	25	8	.74
27	.....do	8	8	3	6	....	25	8	.72
28	Check (unsprayed)	0	1	0	0	2	3	......	5.80
29	.....do	0	0	0	3	0	3	......	7.20
30	.....do	0	2	0	2	0	4	......	5.55

EXPERIMENT X.

FIELD TESTS OF VARIOUS ARSENICALS AGAINST THE CODLING MOTH, 1913.

Field tests were made with the following preparations against the codling moth on apple: Arsenate of lead paste, commercial; arsenate of calcium paste, commercial; arsenate of calcium, homemade, prepared from sodium arsenate and calcium acetate; arsenate of calcium, homemade, prepared from sodium arsenate and calcium chlorid; arsenite of zinc powder, commercial; and arsenate of zinc, homemade. (For methods of preparation of the homemade materials, see p. 2.) All the materials were used in combination with lime-sulphur, 1½ to 50. The spraying was done in Mr. J. T. Beckwith's orchard in the vicinity of Benton Harbor, Mich., the same orchard that was used for the experimental work of the previous season. The results of this experiment are shown in Table X.

98119°—Bull. 278—15——3

TABLE X.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test, Benton Harbor, Mich., 1913.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (paste), 2 pounds to 50 gallons of lime-sulphur solution	1	129	2,144	2,273	94.32
		2	132	2,490	2,622	94.96
		3	135	2,244	2,379	94.32
		4	157	1,850	2,007	92.17
		5	125	1,927	2,052	93.90
	Plat total	......	**678**	**10,655**	**11,333**	**94.01**
II	Arsenate of calcium, homemade (1), at rate of 8/10 pound sodium arsenate to 50 gallons lime-sulphur solution	1	398	2,767	3,165	87.42
		2	208	1,443	1,651	87.40
		3	180	740	920	80.43
		4	254	720	974	73.92
		5	331	976	1,307	74.67
	Plat total	......	**1,371**	**6,646**	**8,017**	**82.89**
III	Arsenate of calcium, homemade (2), at rate of 8/10 pound sodium arsenate to 50 gallons lime-sulphur solution	1	580	2,607	3,187	81.80
		2	388	897	1,285	69.80
		3	497	1,195	1,692	70.62
		4	387	955	1,342	71.16
		5	260	600	860	69.76
	Plat total	......	**2,112**	**6,254**	**8,366**	**74.75**
IV	Arsenate of calcium, commercial (paste), 1⅓ pounds to 50 gallons lime-sulphur solution	1	251	813	1,064	76.41
		2	241	918	1,159	79.20
		3	53	277	330	83.94
		4	240	681	921	73.94
		5	303	1,025	1,328	77.18
	Plat total	......	**1,088**	**3,714**	**4,802**	**77.34**
V	Arsenite of zinc powder, ¾ pound to 50 gallons lime-sulphur solution	1	241	2,345	2,586	90.68
		2	83	978	1,061	92.17
	Plat total	......	**324**	**3,323**	**3,647**	**91.11**
VI	Arsenate of zinc, homemade, at rate of 8/10 pound sodium arsenate to 50 gallons lime-sulphur solution	1	365	2,342	2,707	86.51
		2	503	1,867	2,370	78.78
		3	376	1,731	2,107	82.15
		4	213	1,386	1,599	86.68
		5	186	1,951	2,137	91.92
	Plat total	......	**1,643**	**9,277**	**10,920**	**84.95**
VII	Check (unsprayed)	1	927	877	1,804	48.61
		2	670	503	1,173	42.88
		3	1,082	1,086	2,168	50.01
		4	606	592	1,198	49.41
		5	933	780	1,713	45.53
	Plat total	......	**4,218**	**3,838**	**8,056**	**47.64**

The arsenate of lead plat produced 94.01 per cent of fruit free from codling-moth injury. Arsenate of calcium, homemade (1), fell below this in its efficiency, the percentage of sound fruit being 82.89. Arsenate of calcium, homemade (2), fell still lower in efficiency, producing 74.75 per cent of fruit free from this insect. Each of these materials burned the foliage very slightly. Arsenate of calcium, commercial, produced 77.34 per cent of sound fruit, about an average of the efficiency of the two homemade preparations. The slight burning effect on the foliage amounted to about the same as on the homemade arsenate of calcium plats. Arsenite of zinc powder, commercial, produced 91.11 per cent sound fruit. This material produced moderate burning, about 20 per cent of the leaves being more or less spotted by the spray. Arsenate of zinc, homemade, produced no burning of the foliage and held the codling moth to 84.95 per cent free from worms. The unsprayed plat averaged 47.64 per cent of fruit free from codling-moth injury.

EXPERIMENTS, 1914.

Experiments with various insecticides, alone and combined with fungicides, were made, both at the laboratory and in the field, during the season of 1914. The investigations were continued along the same lines as during the two previous seasons.

The field experiments were conducted in the J. T. Beckwith apple orchard, the John Hamilton pear orchard, both of Benton Harbor, Mich., and the William Birkit vineyard, located at Glenlord, Mich. The field experiments were on a relatively large scale, so that the results represent what may be expected on a commercial basis.

LABORATORY TESTS.

The fall webwoım (*Hyphantria cunea* Drury) was not so abundant as during the seasons of 1912 and 1913, and it was not always possible to secure a sufficient number of young larvæ for the poison-feeding tests. Consequently, when larger larvæ were used, the strength of the poisons was increased to accelerate the killing of the larvæ. However, the same size of larva was used in all lots in each experiment, and the results are therefore comparative.

The laboratory experiments included commercial and homemade insecticides, used alone or combined with a fungicide. Wild-cherry twigs were sprayed by means of a hand atomizer and the spray material allowed to dry thoroughly before placing the larvæ upon the host plant. Time did not permit daily observations, and accordingly the results do not always represent close comparisons, but from a practical point of view they are sufficient.

Experiment XI.

VARIOUS ARSENICALS ALONE AND COMBINED WITH OIL EMULSIONS AGAINST LARVÆ OF THE FALL WEBWORM.

The chief object of this experiment was to ascertain whether the combining of arsenate of lead with kerosene emulsion would affect the individual value of either material for insecticidal purposes.

Other arsenicals, namely, commercial arsenite of zinc and commercial arsenate of calcium, were likewise tested. The results are given in Table XI.

TABLE XI.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started July 17, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.				Total number dead.	Number days required to kill.	Square inches foliage consumed.
		July.		August.				
		23	29	7	13			
1	Kerosene emulsion, 10 per cent	0	0	0	0	0	......	61.00
2	Arsenate of lead powder, 1½–50 + kerosene emulsion, 10 per cent.	10	....	....	....	10	6	0.36
3	Arsenite of zinc powder, 1⅛–50+kerosene emusion, 10 per cent.	10	....	....	....	10	6	0.20
4	Arsenate of calcium, commercial powder, 1½–50+kerosene emulsion, 10 per cent	0	3	6	1	10	27	13.50
5	Anthracene emulsion, 10 per cent	[1]10	....	....	....	10	6	0.01
6	Arsenate of lead powder, 1½–50+anthracene emulsion, 10 per cent	[1]10	....	....	....	10	6	0.01
7	Arsenate of lead powder, 1½–50	10	....	....	....	10	6	0.14
8	Arsenite of zinc powder, 1⅛–50	10	....	....	....	10	6	0.04
9	Arsenate of calcium, commercial powder, 1½–50	10	....	....	....	10	6	0.48
10	Check (unsprayed)	0	0	0	0	0	......	53.00

[1] Foliage badly burned—unfit for consumption.

Kerosene emulsion alone, at a 10 per cent strength, had no poisonous effect upon the fall webworm larvæ—at least none had been killed after having fed for a period of 27 days, with a consumption of 61 square inches of foliage. The arsenate of lead alone killed the 10 larvæ in 6 days—foliage consumed, 0.14 square inch. A combination of these insecticides also caused the death of all the larvæ in 6 days after 0.36 square inch of foliage had been eaten. The other arsenicals, alone or combined with the emulsion (except arsenate of calcium combined), likewise killed in 6 days after a relatively small amount of foliage had been consumed. Arsenate of calcium powder, used alone, was quite as effective as the other arsenicals, but in combination with the emulsion 27 days were required to kill the larvæ, which consumed 13.50 square inches of foliage. A similar result was obtained in a later experiment. (See Experiment XIII.) Anthracene emulsion, 10 per cent, alone and combined with arsenate of lead, burned the foliage badly, rendering it unpalatable.

As shown in Experiment XV, kerosene emulsion, 10 per cent, combined with arsenate of lead is also an effective aphidicide. Although there is some breaking down of the materials in combination, no injury to the foliage was noted in the laboratory tests.

Experiment XII.

COMBINED SPRAYS AGAINST LARVÆ OF THE FALL WEBWORM.

The purpose of Experiment XII was to test by the laboratory method certain spray combinations, some of which were being used under field conditions. The arsenate of calcium used in this experiment was prepared by using 4 pounds of stone lime, to which was added 18 ounces of sodium-arsenate crystals during the slaking. This, when mixed with the proper quantity of water, was used for the making of Bordeaux mixture 4–4–50. This combination was made with a view to using it as a vineyard spray. The results of this experiment appear in Table XII.

Table XII.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started July 24, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.				Total number dead.	Number days required to kill.	Square inches foliage consumed.
		July.		August.				
		29	1	7	13			
1	Arsenate of lead powder, 1½–50+lime-sulphur, 1½–50	7	3	....	....	10	8	0.18
2	Lime-sulphur, 1½–50	5	1	4	....	10	14	0.82
3	Arsenate of lead powder, 1½–50	7	3	....	....	10	8	0.46
4	Commercial sodium sulphid, 2–50	2	4	3	1	10	20	3.34
5	Commercial sodium sulphid, 2–50+arsenate of lead powder, 1½–50	7	3	....	....	10	8	0.22
6	Commercial barium tetrasulphid, 5–50	4	0	5	1	10	20	5.76
7	Commercial barium tetrasulphid, 5–50+arsenate of lead powder, 1½–50	3	6	1	....	10	14	0.34
8	Sodium arsenate (crystals, tech. pure), 18 ounces+Bordeaux mixture, 4–4–50	8	2	....	....	10	8	0.10
9	Sodium arsenate (crystals, tech. pure), 18 ounces+Bordeaux mixture, 4–4–50+nicotine sulphate, 40 per cent, 1–1,600	5	5	....	....	10	8	0.10
10	Check (unsprayed)	1	1	0	0	2	......	13.50

As will be noted in Table XII, arsenate of lead, either alone or combined with lime-sulphur solution or commercial sodium sulphid, killed all the larvæ in 8 days. The same arsenical combined with commercial barium tetrasulphid compound required 14 days to kill the 10 larvæ, although 9 of these were recorded dead at the end of the eighth day. The arsenate of calcium made in the same operation of slaking the stone lime for Bordeaux mixture caused the death of all the larvæ in 9 days. This combination was tested in a vineyard and caused no foliage injury. At the end of 20 days, when the experiment was closed, but two larvæ of the unsprayed lot were dead.

EXPERIMENT XIII.

ARSENATE OF CALCIUM VERSUS ARSENATE OF LEAD, ALONE AND COMBINED WITH KEROSENE EMULSION AND WITH LIME-SULPHUR SOLUTION AGAINST LARVÆ OF THE FALL WEBWORM.

In this experiment a comparative test was made with homemade arsenate of calcium at several strengths, commercial arsenate of calcium, paste and powder, and other materials.

The homemade arsenate of calcium used in this and succeeding experiments was prepared by adding sodium-arsenate crystals to stone lime during the course of slaking.

Formula 1.—Stone lime, 1 pound; sodium arsenate, ½ pound; water, 1½ quarts. This formula, according to chemical analysis, gave a total arsenic oxid (As_2O_5) content of 4.19 per cent; no soluble arsenic oxid.

Formula 2.—Stone lime, 3 pounds; sodium arsenate, 3 pounds; water, 4 quarts; analysis—total arsenic oxid (As_2O_5), 6.16 per cent, no soluble arsenic oxid.

Formula 3.—Stone lime, 4 pounds; sodium arsenate, 2 pounds; water, 4 quarts; analysis—total arsenic oxid (As_2O_5), 3.93 per cent; no soluble arsenic oxid.

Formula 4.—Stone lime, 4 pounds; sodium arsenate, 1 pound; water, 5 quarts; analysis—total arsenic oxid (As_2O_5), 1.88 per cent; no soluble arsenic oxid.

Formula 5.—Stone lime, 3 pounds; sodium arsenate, 1 pound; water, 3 quarts; analysis—total arsenic oxid (As_2O_5), 2.92 per cent; no soluble arsenic oxid.

Formula 6.—Stone lime, 4 pounds; sodium arsenate, 2 pounds; water, 4 quarts; slaking not vigorous; not analyzed.

In all of the homemade formulas lime has been used in considerable excess, with a corresponding decrease of the arsenical content. The commercial arsenate of calcium, paste, showed an analysis of 18.82 per cent total arsenic oxid—soluble arsenic oxid, a trace.

With a view to making a combination spray for peaches and other stone fruits, arsenate of calcium was prepared in the same operation with the making of self-boiled lime-sulphur (8–8–50 formula). As soon as the lime started to slake, 2 pounds of sodium-arsenate crystals and then the sulphur were added and the mixture made up in the usual way. Arsenate of calcium made with self-boiled lime-sulphur may be of value as a spray for stone fruits, owing to the fact that the large excess of lime would tend to prevent burning. Arsenate of calcium, alone, causes injury to peach foliage, unless there is an excess of lime. The calcium on exposure to the atmosphere gradually combines with the carbon dioxid of the air and becomes calcium carbonate, thus releasing some soluble arsenic. For the results of this experiment, see Table XIII.

Arsenate of lead alone killed all larvæ in 8 days; combined with kerosene emulsion, 10 per cent, in 6 days (see Experiment XI); with lime-sulphur in 6 days, and with self-boiled lime-sulphur in 8 days. Commercial arsenate of calcium, powder, required 8 days to kill. Commercial arsenate of calcium, paste, required 27 days, but when combined with lime-sulphur solution, killed in 10 days.

TABLE XIII.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started Aug. 14, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.													Total number dead.	Number days required to kill.	Square inches foliage consumed.
		August—							September—								
		18	20	22	24	26	28	31	2	5	8	10	14	19			
1	Arsenate of lead paste, 4–50	3	6	1	...	...	...	...	...	...	...	...	...	...	10	8	(1)
2	Arsenate of calcium (commercial) paste, 4–50	0	0	0	2	1	0	1	2	1	2	1	...	...	10	27	29.84
3	Arsenate of calcium (commercial) powder, 2–50	1	6	3	...	...	...	...	...	...	...	...	...	...	10	8	1.00
4	Arsenate of calcium paste (homemade, formula 1), 4–50	1	0	1	4	1	1	1	0	0	1	...	...	...	10	25	6.25
5	Arsenate of calcium paste (homemade, formula 1), 4–50	0	0	4	2	1	0	0	0	0	0	1	1	0	9	...	15.50
6	Arsenate of calcium paste (homemade, formula 2), 4–50	0	0	1	7	1	1	...	...	...	...	...	...	...	10	14	6.00
7	Arsenate of calcium paste (homemade, formula 2), 2½–50	0	0	0	0	1	0	1	0	2	1	1	0	1	7	...	33.00
8	Arsenate of calcium paste (homemade, formula 3), 4–50	0	0	1	2	0	0	0	0	0	0	1	2	1	7	...	48.00
9	Arsenate of calcium paste (homemade, formula 3), 4–50	0	0	3	0	0	0	1	2	4	...	...	...	...	10	22	17.00
10	Arsenate of calcium paste (homemade, formula 4), 4–50	0	0	0	0	0	0	0	0	0	0	4	1	4	9	...	61.50
11	Arsenate of calcium paste (homemade, formula 4), 10–50	0	0	2	0	0	2	0	1	1	3	0	0	0	9	...	22.00
12	Arsenate of calcium paste (homemade, formula 5), 4–50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	...	114.00
13	Arsenate of calcium paste (homemade, formula 5), 6–50	0	0	3	1	1	0	0	0	0	0	1	0	2	8	...	18.50
14	Arsenate of calcium paste (homemade, formula 6), 4–50 Slaking, not vigorous	0	2	1	2	0	0	2	2	1	...	...	...	...	10	22	13.00
15	Arsenate of calcium paste (homemade, formula 6), 4–50. Slaking, not vigorous	1	0	2	4	2	1	...	...	...	...	...	...	...	10	14	5.28
16	Arsenate of lead paste, 4–50+kerosene emulsion, 10 per cent	5	5	...	...	...	...	...	...	...	...	...	...	...	10	6	.80
17	Arsenate of calcium paste, commercial, 4–50+kerosene emulsion, 10 per cent	0	0	1	0	0	0	0	0	0	2	0	0	1	4	...	38.00
18	Arsenate of calcium paste (homemade, formula 3)+kerosene emulsion, 10 per cent	0	0	4	2	0	0	1	0	0	2	0	0	0	9	...	38.00
19	Kerosene emulsion, 10 per cent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	...	72.00
20	Arsenate of lead paste, 4–50+lime-sulphur, 1½–50	6	4	...	...	...	...	...	...	...	...	...	...	...	10	6	.31
21	Arsenate of calcium (commercial) paste, 4–50+lime-sulphur, 1½–50	0	0	1	9	...	...	...	...	...	...	...	...	...	10	10	2.00
22	Arsenate of calcium (homemade, formula 3)+lime-sulphur, 1½–50	0	1	1	5	2	1	...	...	...	...	...	...	...	10	14	4.50
23	Sodium arsenate (crystals technically pure), 2 pounds+self-boiled lime-sulphur, 8–8–50	0	0	4	6	...	...	...	...	...	...	...	...	...	10	10	8.00
24	Arsenate of lead paste, 4–50+self-boiled lime-sulphur, 8–8–50	1	8	1	...	...	...	...	...	...	...	...	...	...	10	8	.56
25	Check (unsprayed)	0	0	0	0	0	0	0	0	0	0	0	1	0	1	...	72.00

[1] Not measured.

The homemade arsenate of calcium products, as noted previously, were low in arsenic oxid content, but as a whole proved relatively effective as poisoning agents. Formula (2), arsenic oxid 6.16 per cent, at the rate of 4 to 50, required 14 days, which was the same length of time required by formula (3), arsenic oxid 3.93 per cent, 4 to 50, combined with lime-sulphur solution. The arsenate of calcium prepared along with self-boiled lime-sulphur killed all larvæ in 10 days. The experiment was closed at the end of 36 days, only one larva of the unsprayed lot having died.

Experiment XIV.

ARSENATE OF CALCIUM VERSUS ARSENATE OF LEAD, ALONE AND COMBINED WITH LIME-SULPHUR SOLUTION, AGAINST LARVÆ OF THE FALL WEBWORM.

Homemade arsenate of calcium was again tested in comparison with commercial arsenate of calcium (paste and powder) and arsenate of lead, paste. These arsenicals were used alone and combined with lime-sulphur solution, 1½ to 50. The results of this experiment will be found in Table XIV.

TABLE XIV.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started Aug. 27, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.									Total number dead.	Number days required to kill.	Square inches foliage consumed.
		Aug. 31.	September—										
			2	5	8	10	14	16	19				
1	Arsenate of lead paste, 3-50	0	0	6	4	....	....	....	....		10	12	3.00
2	.....do	0	0	9	1	....	....	....	....		10	12	3.00
3	Arsenate of lead paste, 3-50+lime-sulphur, 1½-50	0	1	6	2	1	....	....	....		10	14	2.25
4	.....do	0	0	7	2	1	....	....	....		10	14	.25
5	Arsenate of lead paste, 5-50	0	0	8	2	....	....	....	....		10	12	2.50
6	.....do	1	2	5	2	....	....	....	....		10	12	3.50
7	Arsenate of lead paste, 5-50+lime-sulphur, 1½-50	0	1	5	4	....	....	....	....		10	12	.50
8	.....do	0	0	3	4	3	....	....	....		10	14	1.50
9	Arsenate of calcium, commercial paste, 5-50	0	0	0	0	0	3	0	1		4	....	63.00
10	.....do	0	0	0	0	4	1	1	0		6	....	38.00
11	Arsenate of calcium, commercial paste, 5-50+lime-sulphur, 1½-50	0	0	3	4	3	....	....	....		10	14	13.50
12	.....do	0	1	1	6	2	....	....	....		10	14	3.75
13	Arsenate of calcium, commercial powder, 2½-50	0	0	0	7	3	....	....	....		10	14	10.50
14	.....do	0	1	2	0	3	4	....	....		10	18	20.05
15	Arsenate of calcium, commercial powder, 2½-50+lime-sulphur, 1½-50	1	0	3	2	4	....	....	....		10	14	4.00
16	.....do	0	1	4	5	....	....	....	....		10	12	1.75
17	Arsenate of calcium (homemade paste, formula 1), 5-50	0	0	0	0	2	1	0	0		3	....	42.00
18	.....do	0	0	0	0	3	0	0	2		5	....	27.50
19	Arsenate of calcium (homemade paste, formula 1), 5-50+lime-sulphur, 1½-50	0	0	4	4	0	2	....	....		10	18	9.25
20	.....do	0	0	2	4	3	0	1	....		10	20	10.00
21	Arsenate of calcium (homemade paste, formula 3), 5-50	0	0	0	0	1	1	1	0		3	....	63.00
22	.....do	0	0	0	0	0	0	0	0		0	....	72.25
23	Arsenate of calcium (homemade paste, formula 3), 5-50+lime-sulphur, 1½-50	0	3	0	1	0	6	....	....		10	18	19.50
24	.....do	0	0	3	3	4	....	....	....		10	14	17.00
25	Lime-sulphur, 1½-50	0	3	2	1	3	0	1	....		10	20	8.00
26	.....do	0	1	3	2	4	....	....	....		10	14	1.25
27	Check (unsprayed)	1	0	0	0	0	0	0	0		1	....	81.00
28	.....do	1	1	0	1	2	0	0	0		5	....	69.25

As will be noted in Table XIV, arsenate of lead as usual killed the larvæ more quickly than any of the other arsenicals. Arsenate of lead paste at the rate of 3 to 50 or 5 to 50 required 12 days to kill all of the larvæ; when combined with lime-sulphur it required slightly longer with a decreased amount of feeding.

As shown in the preceding experiments of 1914, commercial arsenate of calcium when combined with lime-sulphur is a relatively effective poison. Likewise, in this experiment, both lots of the paste form in combination with lime-sulphur killed in 14 days; the powdered form mixed with lime-sulphur in 14 and 12 days.

The homemade arsenate of calcium compounds, when employed with lime-sulphur, were also relatively effective, especially when their low arsenical content is taken into consideration. Homemade arsenate of calcium, formula 1 ($As_2O_5 = 4.19$ per cent), plus lime-sulphur, was effective in killing all the larvæ of both lots in 18 and 20 days. Homemade arsenate of calcium, formula 3 ($As_2O_5 = 3.93$ per cent), required 18 and 14 days.

Experiment XV.

COMPARISON OF THE KILLING EFFECT OF VARIOUS CONTACT POISONS ON APHIS POMI.

A series of laboratory tests was made with various contact insecticides, alone and combined with other materials, against the green apple aphis (*Aphis pomi* De G.). Apple twigs well infested with this species were thoroughly sprayed and then placed in separate glasses containing water. The results were taken one day after date of application. Four tests were made, namely, (1) August 20, p. m.; (2) August 21, a. m.; (3) August 21, p. m.; and (4) September 17. For test (1) all the materials were freshly combined except No. 17, which had been mixed several days previous to its application. The spray materials used in tests (2) and (3) were the same as those employed in test (1), except that they had stood mixed about 18 and 24 hours, respectively, before usage. The chief object of tests (2) and (3) was to ascertain whether or not the mixing of these materials some time in advance of their use would affect their insecticidal value. In test (4) a bucket pump was used for applying the spray, a hand atomizer being used in the other three tests. The results of this experiment appear in Table XV.

TABLE XV.—*Aphis pomi, contact insecticide experiments.*

[Benton Harbor, Mich., 1914.]

Lot No.	Name and dilution.	Per cent of aphides killed.			
		Test 1, Aug. 20, p. m.	Test 2, Aug. 21, a. m.	Test 3, Aug. 21, p. m.	Test 4, Sept. 17.
1	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800	100	100	100	....
2	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+laundry soap, 3–50	100	100	100	100
3	Nicotine sulphate (Com. No. 1), 40 per cent, 1–1,200+laundry soap, 3–50	....	....	....	100
4	Nicotine sulphate (Com. No. 1), 40 per cent, 1–1,600+laundry soap, 3–50	....	....	....	100
5	Nicotine sulphate (Com. No. 1), 40 per cent, 1–2,000+laundry soap, 3–50	....	....	....	100
6	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+arsenate of lead paste, 2–50	100	100	100	....
7	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+arsenate of lead paste, 2–50+laundry soap, 3–50	100	100	100	....
8	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800	100	100	100	....
9	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+arsenate of lead paste, 2–50	100	100	100	....
10	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+laundry soap, 3–50	100	100	100	100
11	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+laundry soap, 3–50+arsenate of lead paste, 2–50	100	100	100	....
12	Kerosene emulsion (66 per cent stock), 1 per cent	....	....	....	0
13	Kerosene emulsion (66 per cent stock), 3 per cent	....	....	....	35
14	Kerosene emulsion (66 per cent stock), 5 per cent	....	....	....	100
15	Kerosene emulsion (66 per cent stock), 10 per cent	100	100	100	100
16	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of lead paste, 2–50	100	100	100	....
[1]17	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of lead paste, 2–50	[2] 95	[2] 98	[2] 98	....
18	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of calcium, commercial paste, 2–50	100	100	100	....
19	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of calcium, commercial paste, 2–50	100	100	100	....
20	Anthracene emulsion (66 per cent stock), 5 per cent	[3] 100	[3] 100	[3] 100	....
21	Anthracene emulsion (50 per cent stock), 3 per cent	....	....	....	100
22	Anthracene emulsion (50 per cent stock), 1 per cent	....	....	....	75
23	Laundry soap, 3–50	[4] 75	[4] 75	[4] 75	15
24	Laundry soap, 5–50	....	....	....	50
25	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+arsenate of lead paste, 2–50+lime-sulphur, 1½–50	100	100	100	....
26	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+arsenate of lead paste, 2–50+lime-sulphur, 1½–50	100	100	100	....
27	Arsenate of lead paste, 2–50	0	[5] 10	0	....
28	Naphtha soap, 3–50	....	....	....	0
29	Naphtha soap, 5–50	....	....	....	0
30	Kerosene emulsion (50 per cent stock—made with naphtha soap, cold water), 10 per cent	....	....	....	85
31	Kerosene emulsion (50 per cent stock—made with naphtha soap, cold water), 5 per cent	....	....	....	50
32	Kerosene emulsion (naphtha soap, cold water), 10 per cent	....	....	....	100
33	Anthracene emulsion (50 per cent stock—made with naphtha soap, cold water), 3 per cent	....	....	....	100
34	Anthracene emulsion (50 per cent stock—made with naphtha soap, cold water), 1 per cent	....	....	....	25
35	Fish-oil soap, 3–50	....	....	....	10
36	Fish-oil soap, 5–50	....	....	....	90
37	Nicotine sulphate (Com. No. 2), 40 per cent, 1–1,200+laundry soap, 3–50	....	....	....	100
38	Nicotine sulphate (Com. No. 2), 40 per cent, 1–1,600+laundry soap, 3–50	....	....	....	100
39	Nicotine sulphate (Com. No. 2), 40 per cent, 1–2,000+laundry soap, 3–50	....	....	....	100
40	Check (unsprayed)	0	0	0	0

[1] Stood combined several days before usage.
[2] A few adults not killed.
[3] Foliage severely burned.
[4] Adult aphides not killed.
[5] No adult aphides killed.

As will be noted in Table XV, the majority of the materials proved effective aphidicides. Thus it will be seen that several combinations may be used with good effect when it is aimed to control both chewing and sucking insects at the same time. It would appear that it is not well to allow kerosene emulsion and arsenate of lead to stand combined too long previous to its application, if the best results are to be obtained. However, a standing for a day or so would make no material difference, since there is but slight breaking down of the soap. In general, insecticides should not be combined until they are to be used. Anthracene emulsion, 5 per cent, burned the foliage badly. Laundry soap, 3 to 50, was effective against the young aphides only. Arsenate of lead alone, as was to be expected, had little or no effect upon the aphides. The combination of arsenate of calcium with kerosene emulsion is not a desirable one, since an insoluble calcium soap is formed, thereby releasing some free kerosene.

According to the results of the above experiment a 10 per cent kerosene emulsion should prove effective against the green apple aphis. In one instance, however, not all of the aphides were killed. The nicotine solutions, with a dilution up to 1 to 2,000 combined with soap, were likewise effective aphidicides. Anthracene emulsion, 3 per cent, gave satisfactory control, and at this strength caused no foliage injury. The kerosene emulsions under 10 per cent were not satisfactory, neither were the soaps at the strengths tested, except that fish-oil soap, 5 to 50, killed 90 per cent of the aphides.

FIELD EXPERIMENTS.

POISON TESTS IN EXPERIMENTAL APPLE ORCHARD.

The Ben Davis orchard which had been used for experimental purposes during the seasons of 1912 and 1913 was again secured for continued investigations. The orchard was in very fair condition and responded very creditably in fruit production, the crop in 1914 being larger than any produced in the past. The experiments included tests of insecticides combined with fungicides, since, in commercial orcharding, a combination spray is usually made. Most of the plats received five spray applications, namely: (1) Dormant application, April 16 and 17; (2) cluster-bud stage, May 5 and 6; (3) when petals dropped, May 23, 25, and 26; (4) three to four weeks later, June 15, 16, and 17; (5) nine weeks after petals dropped, July 27 and 28. The orchard was sprayed with a power outfit having a pressure averaging about 225 pounds.

The results of the investigations as reported in the succeeding pages were obtained from an examination of the fruit. Certain trees in each plat are designated as count trees. The dropped fruit from the count trees was picked up and examined weekly throughout the season, and at harvesting time the picked fruit was likewise examined. The more important results of the experiments for the control of the codling moth are herewith reported.

Experiment XVI.

FIELD TESTS OF ARSENATE OF CALCIUM VERSUS ARSENATE OF LEAD AGAINST THE CODLING MOTH, 1914.

One of the most promising of the insecticides tested during the season of 1914 was an arsenate of calcium paste. A commercial article was employed at the rate of 2 pounds to each 50 gallons of lime-sulphur solution. The plat sprayed with this material consisted of 12 trees, the fruit from five of which was examined throughout the season. The plat sprayed with arsenate of lead paste, 2 pounds combined with 50 gallons lime-sulphur solution, included 12 trees, the fruit from six of which was examined. Plats III, IV, and V, located in different parts of the orchard, were left unsprayed as a check. These plats had a total of eight trees, all of which were examined. Three applications were given Plats I and II, for the control of the codling moth: (1) When petals dropped; (2) three to four weeks later; (3) nine weeks after petals dropped, for the control of the second brood.

The arsenate of calcium paste was analyzed by the Bureau of Chemistry, United States Department of Agriculture, as follows:

Analysis of arsenate of calcium (paste).

	Per cent.
Moisture	55.80
Total arsenic oxid, As_2O_5	18.82
Total calcium oxid, CaO	17.93
Total lead oxid, PbO	3.72
Soluble impurities, exclusive of PbO and As_2O_5	1.84
Water of constitution and undetermined (small amount of CO_2)	1.89
Total	100.00
Soluble arsenic	Trace.

This sample contains lead equivalent to approximately 5.5 per cent lead arsenate. The results of this experiment are shown in Table XVI.

TABLE XVI.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test. A comparison of arsenate of calcium with arsenate of lead. Benton Harbor, Mich., 1914.]

Plat number.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of calcium (commercial paste), 2 pounds to 50 gallons lime-sulphur solution.	1	123	8,087	8,210	98.50
		2	78	5,424	5,502	98.58
		3	47	4,988	5,035	99.06
		4	44	6,132	6,176	99.43
		5	63	4,283	4,346	98.56
	Plat total		**355**	**28,914**	**29,269**	**98.79**

TABLE XVI.—*Sound and wormy apples from sprayed and unsprayed plats*—Contd.

Plat number.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
II......	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution.	1	29	3,777	3,806	99.24
		2	12	2,399	2,411	99.59
		3	28	5,146	5,174	99.46
		4	13	3,833	3,846	99.66
		5	26	3,972	3,998	99.35
		6	26	4,757	4,783	99.46
	Plat total	......	**134**	**23,884**	**24,018**	**99.44**
III-V..	Checks (unsprayed)	1	1,548	3,907	5,455	71.62
		2	3,208	5,556	8,764	63.40
		3	2,342	5,682	8,024	70.81
		4	2,432	4,116	6,548	62.86
		5	2,635	3,722	6,357	58.55
		6	2,385	1,566	3,951	39.64
		7	2,902	2,197	5,099	43.09
		8	2,312	1,356	3,668	36.94
	Plat total	......	**19,764**	**28,102**	**47,866**	**58.71**

As will be noted in Table XVI, out of 29,269 apples from the plat sprayed with arsenate of calcium 98.79 per cent were free from codling moth. The fruit examined on Plat II, 24,018 apples, sprayed with arsenate of lead, was 99.44 per cent free from the codling moth. The unsprayed trees yielded 47,866 apples, of which but 58.71 per cent were free from worms.

It will thus be seen that the arsenate of calcium compared very favorably with the arsenate of lead, and since it can be produced more cheaply than the lead arsenate it would appear to have distinct value. The foliage in Plat I was as healthy appearing as in Plat II throughout the season, and, further, the fungicidal value of lime-sulphur was practically the same, whether arsenate of calcium or arsenate of lead was used. While arsenate of calcium has not been sufficiently tested to recommend it for general use, yet it would seem that this arsenical will probably serve as a satisfactory and cheap substitute for arsenate of lead. Arsenate of calcium may be manufactured either in the paste or powdered form or made at home in the paste form.

HOMEMADE ARSENATE OF CALCIUM.

Arsenate of calcium may be prepared at home from various chemicals, the more important being arsenic acid and lime, sodium arsenate and calcium chlorid, sodium arsenate and calcium acetate, etc. Potassium dihydrogen arsenate may be substituted for the sodium arsenate, but is more expensive and would have no distinct advantages over the latter.

The logical way to make arsenate of calcium is by combining arsenic acid with lime, but at the present writing arsenic acid can not be obtained on the market to advantage. In view of this fact arsenate of calcium may be prepared at home by combining fused (dry powdered) sodium arsenate with lime. The by-product is largely sodium hydroxid, most of which may be decanted. It is possible that decantation will not be necessary when the arsenate of calcium is to be applied to foliage that is not too tender. The formula for making is herewith given:

Stone lime (90 per cent CaO)	pounds	55
Sodium arsenate, fused (dry powdered) 65 per cent As_2O_5	do	100
Water	gallons	26

Place the stone lime in a wooden container and add a small amount of water, just enough to start slaking. When slaking is well under way pour in the sodium arsenate, which should first have been dissolved in hot water. Keep stirring until the lime has thoroughly slaked. Sufficient water should be added from time to time to prevent burning.

The resulting arsenate of calcium should contain about 18 per cent of arsenic oxid. In making this compound it will of course be necessary to know approximately the calcium oxid and arsenic oxid content of the materials employed and to vary the formula accordingly.

Arsenate of calcium was prepared at the laboratory in the proportions as given below:

Stone lime[1] (80 per cent CaO)	pounds	6
Sodium arsenate,[2] fused (dry powdered) 62 per cent As_2O_5	do	10
Water	gallons	2

The above was analyzed by the Bureau of Chemistry, United States Department of Agriculture, as follows:

	Per cent.
Moisture	46.90
Total arsenic oxid, As_2O_5	20.37
Total arsenious oxid, As_2O_3	.21
Calcium oxid, CaO	18.95
Carbon dioxid, CO_2	.18
Undetermined, mainly sodium hydrate	13.39
Total	100.00
Soluble arsenic oxid, As_2O_5	.04

EXPERIMENT XVII.

FIELD TESTS OF POWDERED ARSENATE OF LEAD VERSUS PASTE ARSENATE OF LEAD AGAINST THE CODLING MOTH, 1914.

Since the advent of the powdered form of arsenate of lead the question has naturally arisen as to whether this newer form of the arsenical is as effective as the older or paste form. The powdered arsenate of lead has been on the market for several years and is now being recommended by several manufacturers, who claim for it

[1] This lime was not well burned, since it contained considerable calcium carbonate.

[2] Sodium arsenate, fused (dry powdered) Na_2HAsO_4. As_2O_5=61.86 per cent; As_2O_3=1.42 per cent.

certain advantages. The principal points given in favor of the powder over the paste are that it can be more conveniently mixed, that the proper amount to be used for each spray tank may be weighed out with a greater degree of accuracy, and that it can be stored more readily without deterioration. There is also a distinct saving in freight. For the advantages enumerated the fruit grower is asked to pay a trifle more in price, since it costs the manufacturer somewhat more to produce the powdered form.

With this in view, experiments were conducted to test the efficiency of the powdered form in comparison with the paste. Since the powdered arsenical has approximately twice the strength of the paste, one-fourth pound of the powder was directly compared with one-half pound of the paste, one-half pound of the powder was compared with 1 pound of the paste, and 1 pound of the powder was compared with 2 pounds of the paste. All of these were combined with 50 gallons of lime-sulphur solution, with the exception of Plat IV, where a commercial precipitated sulphur was employed.

Three spray applications against the codling moth were made: (1) when petals dropped; (2) 3 to 4 weeks later; (3) 9 weeks after petals dropped for second-brood larvæ.

The dropped fruit from certain count trees in each plat was picked up weekly and examined. The fruit gathered at harvest time was likewise examined and the results recorded.

Plat I consisted of 9 trees, the fruit from 5 of which was examined; Plat II, 9 trees, 5 examined; Plat III, 4 trees, 3 examined; Plat IV, 5 trees, 3 examined; Plat V, 9 trees, 5 examined; Plat VI, 7 trees, 5 examined; Plat VII, 12 trees, 6 examined; Plats VIII, IX, and X, total 8 trees, 8 examined. For the results of this experiment see Table XVII.

TABLE XVII.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Benton Harbor, Mich., 1914. Poison test. Comparison of arsenate of lead in powdered and paste form.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (powder), ¼ pound to 50 gallons lime-sulphur solution	1	28	667	695	95.97
		2	16	1,036	1,052	98.48
		3	155	3,052	3,207	95.17
		4	117	1,650	1,767	93.38
		5	61	806	867	92.96
	Plat total		**377**	**7,211**	**7,588**	**95.03**
II	Arsenate of lead (paste), ½ pound to 50 gallons lime-sulphur solution	1	387	6,979	7,366	94.75
		2	221	5,282	5,503	95.98
		3	222	5,064	5,286	95.80
		4	355	5,098	5,453	93.49
		5	128	3,771	3,899	96.72
	Plat total		**1,313**	**26,194**	**27,507**	**95.22**

TABLE XVII.—*Sound and wormy apples from sprayed and unsprayed plats*—Contd.

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
III	Arsenate of lead (powder), ½ pound to 50 gallons lime-sulphur solution	1	97	7,250	7,347	98.68
		2	123	5,615	5,738	97.85
		3	68	6,315	6,383	98.93
	Plat total	......	**288**	**19,180**	**19,468**	**98.52**
IV	Arsenate of lead (powder), ½ pound combined with commercial precipitated sulphur, 7 pounds, to 50 gallons water	1	44	5,618	5,662	99.22
		2	93	8,958	9,051	98.97
		3	82	7,791	7,873	98.96
	Plat total	......	**219**	**22,367**	**22,586**	**99.03**
V	Arsenate of lead (paste), 1 pound to 50 gallons lime-sulphur solution	1	74	6,160	6,234	98.81
		2	39	4,163	4,202	99.07
		3	65	4,836	4,901	98.67
		4	64	6,394	6,458	99.01
		5	76	5,787	5,863	98.69
	Plat total	......	**318**	**27,340**	**27,658**	**98.13**
VI	Arsenate of lead (powder), 1 pound to 50 gallons lime-sulphur solution	1	123	5,043	5,166	97.62
		2	41	6,718	6,759	99.39
		3	79	5,418	5,497	98.56
		4	51	7,224	7,275	99.30
		5	121	7,749	7,870	98.46
	Plat total	......	**415**	**32,152**	**32,567**	**98.73**
VII	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution	1	29	3,777	3,806	99.24
		2	12	2,399	2,411	99.59
		3	28	5,146	5,174	99.46
		4	13	3,833	3,846	99.66
		5	26	3,972	3,998	99.35
		6	26	4,757	4,783	99.46
	Plat total	......	**134**	**23,884**	**24,018**	**99.44**
VIII–X	Checks (unsprayed)	1	1,548	3,907	5,455	71.62
		2	3,208	5,556	8,764	63.40
		3	2,342	5,682	8,024	70.81
		4	2,432	4,116	6,548	62.86
		5	2,635	3,722	6,357	58.55
		6	2,385	1,566	3,951	39.64
		7	2,902	2,197	5,099	43.09
		8	2,312	1,356	3,668	36.94
	Plat total	......	**19,764**	**28,102**	**47,866**	**58.71**

As will be noted in Table XVII, there is practically no difference from an insecticidal point of view in the effectiveness of the powdered and the paste arsenate of lead. The fruit grower would be justified in using the powdered form if the present difference in cost is considered reasonable for the advantages secured.

One-fourth pound of the powdered arsenate of lead gave 95.03 per cent of fruit free from codling moth against 95.22 per cent where one-half pound of the paste was used. The two plats sprayed with one-half pound of the powder gave 98.52 and 99.03 per cent of sound fruit, respectively, as compared with 98.13 per cent for 1 pound of the paste. One pound of the powder averaged 98.73 per cent sound against 99.44 per cent for 2 pounds of the paste. The unsprayed trees yielded 47,866 apples, of which number 58.71 per cent were free from codling-moth infestation.

EXPERIMENT XVIII.

FIELD TESTS OF VARIOUS ARSENICALS COMBINED WITH FUNGICIDES AGAINST THE CODLING MOTH, 1914.

Arsenate of lead was tested against the codling moth in combination with the following commercial fungicides, namely, lime-sulphur, commercial; precipitated sulphur, commercial; sodium sulphid, commercial; and commercial barium tetrasulphid compound. The following combinations were also tested:

Arsenite of zinc (paste) was used at the rate of 1½ pounds combined with Bordeaux mixture 4–4–50. This arsenical was added to the lime while being slaked for the Bordeaux mixture.

Arsenite of zinc (paste), 1½ pounds, was added to 2 pounds stone lime while the lime was slaking. This was mixed with 50 gallons lime-sulphur solution.

Arsenate of zinc (homemade), prepared from sodium arsenate crystals and zinc sulphate, was used at the rate of eight-tenths pound sodium arsenate to 50 gallons lime-sulphur solution. Three spray applications were made with the above combinations. The results of this experiment will be found in Table XVIII.

TABLE XVIII.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test. Miscellaneous. Benton Harbor, Mich., 1914.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution.	1	29	3,777	3,806	99.24
		2	12	2,399	2,411	99.59
		3	28	5,146	5,174	99.46
		4	13	3,833	3,846	99.66
		5	26	3,972	3,998	99.35
		6	26	4,757	4,783	99.46
	Plat total		**134**	**23,884**	**24,018**	**99.44**
II	Arsenate of lead (powder), ½ pound + commercial precipitated sulphur, 7 pounds, to 50.	1	44	5,618	5,662	99.22
		2	93	8,958	9,051	98.97
		3	82	7,791	7,873	98.96
	Plat total		**219**	**22,367**	**22,586**	**99.03**
III	Arsenate of lead (paste), 2 pounds + commercial sodium sulphid, 2 pounds, to 50.	1	72	7,898	7,970	99.08
		2	30	7,784	7,814	99.62
		3	34	8,739	8,773	99.61
	Plat total		**136**	**24,421**	**24,557**	**99.45**
IV	Arsenate of lead (paste), 2 pounds + stone lime, 2 pounds + commercial sodium sulphid, 2 pounds, to 50.	1	35	8,295	8,330	99.58
		2	22	6,269	6,291	99.65
		3	39	9,639	9,678	99.60
	Plat total		**96**	**24,203**	**24,299**	**99.65**

TABLE XVIII.—*Sound and wormy apples from sprayed and unsprayed plats*—Contd.

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
V	Arsenate of lead (paste), 2 pounds + commercial barium tetrasulphid 5–50.	1	806	9,224	10,030	90.97
		2	450	7,864	8,314	94.59
		3	216	6,988	7,204	97.00
		4	258	7,107	7,365	97.85
		5	328	10,340	10,668	96.91
	Plat total	......	**2,058**	**41,523**	**43,581**	**95.28**
VI	Arsenite of zinc (paste), 1½ pounds + Bordeaux mixture 4–4–50.	1	42	3,982	4,024	98.96
		2	29	5,121	5,150	99.44
		3	27	3,231	3,258	99.17
	Plat total	......	**98**	**12,334**	**12,432**	**99.21**
VII	Arsenite of zinc (paste), 1½ pounds + stone lime, 2 pounds, to 50 gallons lime-sulphur solution.	1	347	4,092	4,439	92.18
		2	244	5,478	5,722	95.74
		3	274	5,885	6,159	90.68
	Plat total	......	**865**	**15,455**	**16,320**	**94.70**
VIII	Arsenate of zinc (homemade), sodium arsenate crystals, $\frac{8}{10}$ pound, to 50 gallons lime-sulphur solution	1	221	3,654	3,875	94.30
		2	167	3,544	3,711	95.50
		3	309	5,306	5,615	94.50
	Plat total	......	**697**	**12,504**	**13,201**	**94.72**
IX–XI	Checks (unsprayed)	1	1,548	3,907	5,455	71.62
		2	3,208	5,556	8,764	63.40
		3	2,342	5,682	8,024	70.81
		4	2,432	4,116	6,548	62.86
		5	2,635	3,722	6,357	58.55
		6	2,385	1,566	3,951	39.64
		7	2,902	2,197	5,099	43.09
		8	2,312	1,356	3,668	36.94
	Plat total	......	**19,764**	**28,102**	**47,866**	**58.71**

Arsenate of lead gave satisfactory control of the codling moth when combined with lime-sulphur, commercial precipitated sulphur, and commercial barium tetrasulphid. In combination with commercial sodium sulphid, lead arsenate held the codling moth in check, but caused considerable foliage injury and defoliation due to the formation of soluble sodium arsenate. The addition of lime lessened the foliage injury somewhat.

Arsenate of zinc, when added to lime being slaked for Bordeaux mixture, was effective and caused no foliage injury. Arsenite of zinc added to slaking lime and then mixed with lime-sulphur solution, and likewise arsenate of zinc (homemade) combined with lime-sulphur solution, were slightly less effective than the other arsenical combinations.

EXPERIMENT XIX.

COMBINATION SPRAYS—COMPATIBLES AND INCOMPATIBLES.

Combination sprays for the control of apple chewing and sucking insects and fungous diseases were tested in the experimental orchard. Arsenate of lead with nicotine solutions and lime-sulphur solution is a compatible mixture and will give satisfactory results if the application is timely:

Arsenate of lead, kerosene emulsion, and lime-sulphur in combination is an incompatible mixture, usually causing severe injury to the foliage. The calcium of the lime-sulphur breaks down the soap of the kerosene emulsion, forming an insoluble calcium soap. The result is that free kerosene is released in sufficient quantity to cause foliage injury.

A combination of lime-sulphur and kerosene emulsion, 10 per cent, was tested on apple in the cluster-bud stage to determine the extent of damage likely to occur. The plat which later received one-fourth pound to 50 of powdered arsenate of lead was used for the test. Both the foliage and unopened blossoms were so seriously injured as to reduce materially the size of the crop.

By reference to Table XVII the effect upon the crop yield will be noted. All plats in this table having five count trees were sprayed with lime-sulphur alone during the cluster-bud stage except Plat I. Plat I, which was sprayed with the combination of lime-sulphur and kerosene emulsion, yielded 7,588 apples (39 bushels); Plat II, 27,507 apples (109.5 bushels); Plat V, 27,658 apples (118 bushels); Plat VI, 32,567 apples (128.5 bushels). The number of bushels represents the amount of fruit picked from the trees at harvest time. An estimate of the loss of crop per tree due to the application of lime-sulphur and kerosene emulsion is approximately 16 bushels, or, in other words, the normal crop yield was reduced to about 33 per cent of that from the lime-sulphur plats alone.

Lime-sulphur and soap in combination is likewise impracticable, since a calcium soap is thrown out, thus weakening the value of each material.

Diplumbic arsenate of lead, especially the powdered form which is chiefly diplumbic, is likely to cause foliage injury when combined with an alkalin solution, such as sodium sulphid. But when combined with lime-sulphur some calcium arsenate is formed. This is comparatively insoluble, and hence the possibility of burning is reduced.

Experiment XX.

COMPARISON OF SODA, POTASH, AND SULPHUR SPRAYS AGAINST THE SAN JOSE SCALE.

The pear orchard owned by Mr. John Hamilton, of Benton Harbor, Mich., was used for the San Jose scale insecticide investigations. This orchard consisted of 209 trees about 15 years of age. Four varieties, planted in separate rows, were represented as follows: Three rows of Bartlett, one row Clairgeau, three rows Beurré d'Anjou, and one row Seckle. This orchard had been more or less neglected for several years and was accordingly quite uniformly infested with the scale. The orchard was divided into nine plats so as to include all varieties in each plat, so far as possible. Trees were left unsprayed at each end of the orchard and also in central sections as a basis for comparison with the sprayed. The spray materials were applied while the trees were dormant, April 10, 11, and 13, using a small power outfit.

To determine the efficacy of the scale insecticides two methods were employed; first, the examination of the scale-infested twigs for dead and live scales by means of the binocular microscope. This method proved to be anything but satisfactory. The second and better method of determining results was the examination of the fruit for scale which crawled thereon. All of the dropped fruit from the count trees was picked up and examined weekly throughout the season. The picked fruit at harvest time was also examined. In Table XIX will be found the results according to variety. Table XX is a commercial summary of Table XIX.

As will be noted in Table XX (commercial summary), the percentage of fruit (all varieties) free from scale and that with a light infestation has been combined for a comparison with the percentage of fruit with an infestation medium and heavy. The scale upon the fruit classified as lightly infested was usually found more or less concealed in the calyx cavity and, therefore, did not mar the appearance of the fruit for market. Furthermore, a large percentage of the fruit lightly infested had but two or three scales per fruit.

The fruit with a medium and heavy scale infestation was unmarketable. Frequently the fruit in the heavy scale infestation class was blood red in appearance and would average 500 to 1,000 scales per fruit. This condition was chiefly found on the unsprayed trees, whose foliage was likewise heavily infested with the scale insects.

TABLE XIX.—*San Jose scale insecticide investigations, Benton Harbor, Mich., 1914.*

Plat.	Name and dilution.	Number of count trees.				Number of fruits.				Per cent of fruit. Free from scale.			
		Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.
I	Lime-sulphur, 1-7	8	3	5	3	1,841	453	242	389	75.667	53.201	51.241	68.637
II	(1) Commercial sodium sulphid, 12.5 pounds-50	5	2	2	1	1,717	306	94	10	59.059	41.505	20.215	90.000
III	Caustic potash, 11 pounds+sulphur, 12.5 pounds-50	2	0	3	2	1,008	0	191	1,522	25.101	......	30.892	39.490
IV	(2) Commercial sodium sulphid, 12.5 pounds-50	0	2	3	0	0	435	238	0	......	38.622	32.774	......
V	Caustic soda, 11 pounds+sulphur, 12.5 pounds-50	4	1	2	0	1,865	139	140	0	78.709	34.559	41.430	......
VI	Lime-sulphur, 1-7+nitrate of soda, 50 pounds-50	6	0	2	2	946	0	113	15	76.289	......	50.445	80.000
VII	Caustic soda, 15 pounds+sulphur, 17.1 pounds-50	5	1	2	1	1,531	143	208	521	89.877	51.750	70.194	54.892
VIII	Caustic potash, 15 pounds+sulphur, 17.1 pounds-50	4	1	3	0	1,116	179	263	0	89.247	78.771	51.716	......
IX	Check—unsprayed	33	2	11	3	8,100	299	1,825	4,474	52.595	25.420	8.056	6.841

TABLE XIX.—*San Jose scale insecticide investigations, Benton Harbor, Mich., 1914*—Continued.

Plat.	Name and dilution.	Per cent of fruit.											
		Light infestation, 1-10 scales.				Medium infestation, 11-20 scales.				Heavy infestation, 21-over scales.			
		Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.
I	Lime-sulphur, 1-7	23.954	33.554	38.016	26.737	0.271	13.245	8.677	3.598	0.108	0	2.066	1.028
II	(1) Commercial sodium sulphid, 12.5 pounds-50	36.167	50.000	67.021	10.000	3.377	6.535	6.382	0	1.397	1.960	6.382	0
III	Caustic potash, 11 pounds+sulphur, 12.5 pounds-50	61.111	......	49.738	42.312	11.011	......	7.339	6.570	2.777	......	12.041	11.628
IV	(2) Commercial sodium sulphid, 12.5 pounds-50	......	46.666	39.916	......	......	12.873	14.705	......	......	1.839	12.605	......
V	Caustic soda, 11 pounds+sulphur, 12.5 pounds-50	20.005	36.690	48.571	......	1.018	21.561	7.857	......	.268	7.19	2.142	......
VI	Lime-sulphur, 1-7+nitrate of soda, 50 pounds-50	22.305	......	40.707	20.000	1.313	......	5.309	0	.093	......	3.539	0
VII	Caustic soda, 15 pounds+sulphur, 17.1 pounds-50	9.797	46.153	28.365	39.731	.261	1.398	.961	4.418	.065	.699	.480	.959
VIII	Caustic potash, 15 pounds+sulphur, 17.1 pounds-50	10.663	21.229	43.722	......	.090	0	2.661	......	0	0	1.901	......
IX	Check—unsprayed	25.654	48.829	18.356	33.281	6.358	14.046	9.205	18.506	15.393	11.705	64.383	41.372

TABLE XX.—*San Jose scale insecticide investigations (commercial table), Benton Harbor, Mich., 1914.*

Plat.	Name and dilution.	Number of count trees.	Total number of fruits.	Per cent of fruit.	
				Free from scale to light infestation, marketable.	Medium to heavy infestation, unmarketable.
I	Lime-sulphur, 1-7	19	2,925	98.052	1.948
II	(1) Commercial sodium sulphid, 12.5 pounds-50	11	2,127	94.359	5.641
III	Caustic potash, 11 pounds+sulphur, 12.5 pounds-50	7	2,721	83.352	16.648
IV	(2) Commercial sodium sulphid, 12.5 pounds-50	5	673	80.833	19.167
V	Caustic soda, 11 pounds+sulphur, 12.5 pounds-50	7	2,144	97.942	2.058
VI	Lime-sulphur, 1-7+nitrate of soda, 50 pounds-50	11	1,074	98.511	1.489
VII	Caustic soda, 15 pounds+sulphur, 17.1 pounds-50	8	2,403	98.378	1.622
VIII	Caustic potash, 15 pounds+sulphur, 17.1 pounds-50	8	1,558	99.167	.833
IX-XI	Checks—unsprayed	49	14,693	60.793	39.207

Although the spray materials were subjected to a severe test, all, with the exception of the materials employed in Plats III and IV, gave satisfactory results. Lime-sulphur was used alone and also in combination with nitrate of soda. The addition of sodium nitrate did not affect the insecticidal value of the lime-sulphur. These plats yielded 98.052 and 98.511 per cent of marketable fruit, respectively. The homemade sodium and potassium sulphur solutions, with the exception of the materials used in Plat III, gave 97.972 to 99.167 per cent of marketable fruit. Plat III (KOH, 11 pounds, and sulphur, 12.5 pounds), 83.352 per cent, No. 2 commercial sodium sulphid 80.833 per cent, and the unsprayed plats averaged but 60.793 per cent of marketable fruit.

Experiment XXI.

FIELD TESTS OF VARIOUS ARSENICALS COMBINED WITH BORDEAUX MIXTURE ON THE FOLIAGE OF GRAPE.

Several arsenicals in combination with Bordeaux mixture (4–4–50) were tested on grape foliage at the vineyard of William Birkit, of Glenlord, Mich. Two applications were made with a power sprayer, June 23 and July 2, 1914, 50 gallons to the plat.

Plat I (applications 1 and 2), commercial arsenate of lead (powder), 1½ to 50; Plat II (applications 1 and 2), arsenate of calcium, homemade (sodium arsenate crystals, 18 ounces + calcium chlorid to 50); Plat III (applications 1 and 2), arsenate of zinc, homemade (sodium arsenate crystals, 18 ounces + zinc sulphate to 50); Plat IV (application 1), commercial arsenate of calcium (paste), 3 to 50, (application 2) homemade arsenate of calcium (sodium arsenate crystals, 18 ounces + stone lime, 3 pounds to 50); Plat V (application 1), commercial arsenite of zinc (paste), 1¾ to 50 (application 2), commercial arsenite of zinc (powder), 18 ounces to 50.

No foliage injury resulted from the applications of these arsenicals.

SUMMARIZED REVIEW.

ARSENATE OF LEAD.

LABORATORY TESTS.

Used alone.—Arsenate of lead was used throughout the experimental work as a basis of comparison for the other compounds tested. The rapidity of killing was greatest with diplumbic arsenate of lead, while the triplumbic form was the slowest. Arsenate of lead of a mixed diplumbic and triplumbic composition closely approached the effectiveness of the diplumbic form. Commercial arsenate of lead No. 1 (triplumbic) was likewise slower in killing than the other commercial compounds, which were largely diplumbic. In tests with the several forms of arsenate of lead upon tender foliage, the triplumbic, the most insoluble form, was found to be the safest.

With kerosene emulsion.—Arsenate of lead may be combined with kerosene emulsion for the purpose of combating mandibulate and haustellate insects. Although there is a slight breaking down of the materials, the value of neither material is depreciated when used jointly as a spray. In order to secure the best results, it is advisable not to mix these materials until needed. In a general way this is applicable to the use of most insecticides in combination.

With lime-sulphur.—Triplumbic arsenate of lead combined with lime-sulphur solution again proved to have a slower toxic effect than either di or di and tri arsenates so combined. The triplumbic commercial No. 1 arsenate of lead was again less rapid as a poisoning agent than the commercial products of diplumbic compositions. It was found that the mixing of lime-sulphur and arsenate of lead results in a smaller consumption of foliage than when arsenate of lead is used alone.

FIELD TESTS WITH APPLES.

With lime-sulphur.—Arsenate of lead consistently proved to be the most effective poison tested during the three years of experimentation. Triplumbic arsenate with lime-sulphur did not hold the codling moth in check quite as well as the ordinary commercial (diplumbic) arsenate of lead. Powdered arsenate of lead is equally as effective as the paste form for the control of the codling moth.

LABORATORY AND FIELD TESTS.

With commercial sodium sulphid No. 1.—The value of arsenate of lead is not decreased when combined with sodium sulphid; in fact the sodium arsenate formed is more active as a toxin than lead arsenate. However, field experiments with apples show that this combination is impracticable, owing to the frequency of foliage injury due to the formation of the soluble sodium arsenate.

With commercial barium tetrasulphid.—Arsenate of lead mixed with barium tetrasulphid was used with satisfactory results for the control of the codling moth. This combination was found safe for use on apple foliage.

With nicotine solutions and lime-sulphur.—Arsenate of lead may be mixed with nicotine solutions and lime-sulphur for the control of certain apple sucking and chewing insects, as well as fungous diseases. The mixing of these materials does not lessen their individual value and moreover may be applied to apple foliage with safety.

With kerosene emulsion and lime-sulphur.—The combination of lead arsenate, kerosene emulsion, and lime-sulphur should not be used as an orchard spray, owing to the breaking down of the materials and the subsequent foliage injury.

With fish-oil soap and lime-sulphur.—The combination of arsenate of lead, fish-oil soap, and lime-sulphur is not a compatible mixture for spraying purposes, since an insoluble calcium soap is formed. In our experience, any combination containing lime-sulphur and soap should not be used.

ARSENATE OF CALCIUM.

An effort was made to secure a satisfactory substitute for arsenate of lead, a compound which would be as efficient and at the same time less costly. With this object in view arsenate of calcium was used in the experimental work during 1912, 1913, and 1914, and has given encouraging results. This arsenical can undoubtedly be manufactured at a somewhat cheaper cost than arsenate of lead. It is of further interest to note that this compound may be readily prepared at home by combining fused sodium arsenate with stone lime. (For a discussion of the method of making, see p. 30.) While it would be preferable to use arsenic acid in place of sodium arsenate, this acid can not be readily secured at low cost at the present time. When arsenic acid is used the method of preparation as described should be modified somewhat.

LABORATORY TESTS.

Used alone.—Arsenate of calcium, commercial powder and paste and homemade paste, in accordance with several formulas, was used in poison-feeding tests with several species of chewing insects. In some instances the rapidity of killing was equal to that of arsenate of lead, but was generally somewhat less.

With lime-sulphur.—With lime-sulphur, arsenate of calcium was as a rule more effective as a poisoning agent than when used alone. When these compounds are combined, the amount of foliage consumed by the larvæ is less than when arsenate of calcium is used alone.

FIELD TESTS WITH APPLES.

With lime-sulphur.—During the years 1912 and 1913 the several forms of arsenate of calcium combined with lime-sulphur gave fairly satisfactory control of the codling moth, considering the strength of the arsenical used. In 1914 a commercial arsenate of calcium (paste), arsenic oxid 18.82 per cent, combined with lime-sulphur solution, gave very excellent control of the codling moth in comparison with arsenate of lead and unsprayed plats; arsenate of calcium, 29,269 apples, 98.79 per cent sound; arsenate of lead, 24,018 apples, 99.44 per cent sound; unsprayed, 47,866 apples, 58.71 per cent sound. It is of further interest to note that arsenate of calcium may be combined with lime-sulphur without lessening the value of the latter as a fungicide.

FIELD TESTS WITH GRAPE.

With Bordeaux mixture.—Commercial arsenate of calcium and homemade compounds were used combined with Bordeaux mixture in vineyard experiments. These combinations caused no foliage injury.

ARSENATE OF IRON.

LABORATORY AND FIELD TESTS.

Arsenate of iron is a slower acting poison than many of the other arsenicals tested. Laboratory tests, even at increased strengths, show that this arsenical is not quick to kill. In the field tests at the experimental apple orchard arsenate of iron was not an effective insecticide for the codling moth. When used at greater strengths, however, this arsenical should give fairly satisfactory results, but would have no advantages over arsenate of lead.

ARSENATE OF ZINC.

LABORATORY AND FIELD TESTS.

Arsenate of zinc was used with very fair success in laboratory and field tests, but fell somewhat below the efficiency of arsenate of lead. This arsenical has no distinct advantages over arsenate of lead.

ARSENITE OF LIME.

LABORATORY AND FIELD TESTS.

Arsenite of lime is an active and relatively cheap arsenical poison. Unfortunately, however, its use is frequently attended with injury to the foliage.

ARSENITE OF ZINC.

LABORATORY AND FIELD TESTS.

Arsenite of zinc was used in both the paste and powdered forms alone and combined with fungicides. In common with other arsenites the zinc compound is an active poison, but frequently causes foliage injury. Arsenite of zinc combined with milk of lime and arsenite of zinc mixed with lime-sulphur caused considerable burning in the experimental apple orchard during 1912. In 1914 arsenite of zinc (paste) added to slaking lime and then mixed with lime-sulphur solution gave practically no foliage injury, but the value of the arsenical was apparently impaired. Arsenite of zinc (paste) added to slaking lime for Bordeaux mixture gave excellent codling-moth control and caused no foliage injury. It is possible that the latter combination may be of value in sections where apple growers use Bordeaux mixture along with an arsenical for the control of the codling moth, bitter-rot, and blotch. Commercial arsenite of zinc in combination with Bordeaux mixture was tested in a vineyard during the season of 1914, with satisfactory results.

MISCELLANEOUS ARSENICALS.

The following arsenical compounds were also tested at the laboratory: Arsenic sulphid, arsenic tersulphid, and arsenic trioxid. These materials are destructive to leaf tissue and therefore undesirable insecticides.

Nonarsenical Compounds.

Several compounds containing no arsenic were tested, namely, barium chlorid, barium sulphate, calcium chlorid, copper oxid, lead acetate, lead carbonate, lead chromate, lead oxid, lead peroxid, mercury bichlorid, zinc chlorid, zinc oxid, and zinc sulphate. While some of these compounds gave more or less satisfactory results, they were not of sufficient promise to warrant further testing.

SODIUM AND POTASSIUM SULPHUR SOLUTIONS.

Caustic soda and caustic potash (homemade and commercial) were combined with sulphur for the control of the San Jose scale. Certain of the solutions proved to be generally satisfactory as scalecides, in some instances equaling lime-sulphur solution. Such solutions can be readily prepared at home without the use of heat.

CONCLUSIONS.

During the course of the experimental work information on the value of many compounds and combination sprays has been secured. Several of the materials proved to be less valuable than those now in common use, owing to their slow killing effect, to their injury to foliage, to their cost, or to their incompatibility. While many of the compounds proved to be impracticable for insecticidal purposes, certain new spray materials and combinations were used with success. Since the prevention of fungous diseases is intimately associated with insect control, many of the insecticides were tested with a fungicide in order to ascertain the results of such a combination.

Arsenate of lead proved to be the most consistent and valuable stomach poison tested, giving satisfactory results throughout the experimental work.

Arsenate of lead is equally effective in either the paste or powdered form.

Triplumbic arsenate of lead is less rapid as a poisoning agent than diplumbic arsenate, but is safer for use on tender foliage.

Arsenate of lead may be combined with nicotine solutions and lime-sulphur solution for the control of certain apple chewing and sucking insects, and fungous diseases.

For the control of certain sucking and chewing insects arsenate of lead may be combined with kerosene emulsion.

Arsenate of lead, kerosene emulsion, and lime-sulphur is an incompatible mixture, due to the formation of an insoluble calcium soap and the subsequent release of free kerosene. In our experience any combination containing lime-sulphur and soap should not be used, owing to the formation of an insoluble calcium soap.

Arsenate of lead should not be mixed with sodium sulphid compounds, since the soluble sodium arsenate formed is destructive to leaf tissue.

Arsenate of lead combined with a commercial barium tetrasulphid gave satisfactory control of the codling moth and caused no foliage injury in the experimental apple orchard.

The most promising new insecticide developed during the course of the experimental work is arsenate of calcium. This arsenical may be manufactured at less cost than arsenate of lead or may be readily prepared at home as described on page 30. During the seasons of 1912 and 1913 arsenate of calcium gave encouraging results. In 1914 a commercial arsenate of calcium paste in combination with lime-sulphur gave very satisfactory control of the codling moth. While arsenate of calcium may have certain limitations, it will doubtless prove of value for the control of chewing insects on certain host plants.

Arsenate of iron and arsenate of zinc are not as satisfactory as arsenate of lead.

Arsenite compounds are dangerous to use on tender foliage. In some instances, however, it may be possible to prevent foliage injury somewhat by combining the soluble arsenic with lime.

Sodium-sulphur and potassium-sulphur compounds gave fairly satisfactory control of the San Jose scale, in some instances equaling lime-sulphur solution. They may readily be prepared at home without the use of heat.

KEY TO THE TABLES OF INSECTICIDES AND COMBINATION SPRAYS USED IN THIS BULLETIN.

[Com=commercial; c. p.=chemically pure; h. m.=homemade.]

Reference.	Table.
Anthracene emulsion	XI, XV
Anthracene emulsion, arsenate of lead (powder)	XI
Arsenate of calcium (com. paste)	VI, XIII, XIV
Arsenate of calcium (com. paste), kerosene emulsion	XIII
Arsenate of calcium (com. paste), lime-sulphur	VI, X, XIII, XIV, XVI
Arsenate of calcium (com. powder)	VIII, XI, XIII, XIV
Arsenate of calcium (com. powder), kerosene emulsion	XI
Arsenate of calcium (com. powder), lime-sulphur	XIV
Arsenate of calcium (c. p. powder)	I, III, V
Arsenate of calcium (c. p. powder), lime	V
Arsenate of calcium (c. p. powder), lime-sulphur	II, IV, V
Arsenate of calcium (h. m. paste)	VI, VIII, IX, XIII, XIV
Arsenate of calcium (h. m. paste), Bordeaux mixture	XII
Arsenate of calcium (h. m. paste), Bordeaux mixture, nicotine sulphate	XII
Arsenate of calcium (h. m. paste), kerosene emulsion	XIII
Arsenate of calcium (h. m. paste), lime-sulphur	VI, X, XIII, XIV
Arsenate of calcium (h. m.), self-boiled lime-sulphur	XIII
Arsenate of iron (c. p. powder)	I, III, V
Arsenate of iron (c. p. powder), lime	V
Arsenate of iron (c. p. powder), lime-sulphur	II, IV, V
Arsenate of iron (h. m. paste)	I, III, V
Arsenate of iron (h. m. paste), lime	V
Arsenate of iron (h. m. paste), lime-sulphur	II, IV, V
Arsenate of lead (com. paste)	I, III, V, VI, VII, VIII, IX, XIII, XIV, XV
Arsenate of lead (com. paste), barium tetrasulphid	XVIII
Arsenate of lead (com. paste), kerosene emulsion	XIII

	Table.
Arsenite of zinc (c. p. powder), lime	V
Arsenite of zinc (c. p. powder), lime-sulphur	II, V
Barium chlorid	I
Barium chlorid, lime-sulphur	II
Barium sulphate	I
Barium sulphate, lime-sulphur	II
Barium tetrasulphid (com.)	XII
Barium tetrasulphid (com.), arsenate of lead (com. paste)	XVIII
Barium tetrasulphid (com.), arsenate of lead (com. powder)	XII
Bordeaux mixture, arsenate of calcium (h. m. paste)	XII
Bordeaux mixture, arsenate of calcium (h. m. paste), nicotine sulphate	XII
Bordeaux mixture, arsenite of zinc (com. paste)	XVIII
Calcium chlorid	I
Calcium chlorid, lime-sulphur	II
Copper oxid	I
Copper oxid, lime-sulphur	II
Kerosene emulsion	XI, XIII, XV
Kerosene emulsion, arsenate of calcium (com. paste)	XIII, XV
Kerosene emulsion, arsenate of calcium (com. powder)	XI
Kerosene emulsion, arsenate of calcium (h. m. paste)	XIII
Kerosene emulsion, arsenate of lead (com. paste)	XIII, XV
Kerosene emulsion, arsenate of lead (com. powder)	XI
Kerosene emulsion, arsenite of zinc (com. powder)	XI
Lead acetate	I
Lead acetate, lime-sulphur	II
Lead carbonate	I
Lead carbonate, lime-sulphur	II
Lead chromate (com. powder)	I, VII, VIII, IX
Lead chromate (com. powder), lime-sulphur	II
Lead chromate (h. m. paste)	VII, VIII
Lead oxid	I
Lead oxid, lime-sulphur	II
Lead peroxid	I
Lead peroxid, lime-sulphur	II
Lime, arsenate of calcium (c. p. powder)	V
Lime, arsenate of iron (c. p. powder)	V
Lime, arsenate of iron (h. m. paste)	V
Lime, arsenate of lead (com. paste)	V
Lime, arsenate of lead (com. paste), sodium sulphid (com.)	XVIII
Lime, arsenate of lead (diplumbic powder)	V
Lime, arsenate of lead (di and triplumbic powder)	V
Lime, arsenate of lead (triplumbic powder)	V
Lime, arsenate of lead (triplumbic paste)	V
Lime, arsenate of zinc (c. p. powder)	V
Lime, arsenate of zinc (h. m. paste)	V
Lime, arsenite of lime (h. m. paste)	V
Lime, arsenite of zinc (com. paste)	V
Lime, arsenite of zinc (com. paste), lime-sulphur	XVIII
Lime, arsenite of zinc (com. powder)	V
Lime, arsenite of zinc (c. p. powder)	V
Lime, paris green	V
Lime-sulphur	II, V, XII, XIV, XIX, XX
Lime-sulphur, arsenate of calcium (com. paste)	VI, X, XIII, XIV, XVI

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 279

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

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SINGLE-STALK COTTON CULTURE AT SAN ANTONIO.

By ROWLAND M. MEADE, *Scientific Assistant, Office of Crop Acclimatization.*

CONTENTS.

INTRODUCTION.

Single-stalk cotton culture, as explained and discussed in previous publications of the Bureau of Plant Industry,[1] has proved more satisfactory than other systems of culture in various sections of the cotton belt, especially in regions having short seasons. This is so for two reasons: (1) Single-stalk culture promotes earliness and (2) it increases the acre yield. The single-stalk system of cotton culture embraces late thinning and short spaces between the plants in the row. The late thinning suppresses the vegetative branches and restricts the size of the plants, so that they can be left from 6 to 12 inches apart in the row without injurious crowding. The plants are left close together, so that the row space is more efficiently utilized and higher yields are obtained than by the common system of wide spacing.

[1] The publications of the Bureau of Plant Industry concerning the single-stalk system of cotton culture are as follows: "A New System of Cotton Culture," a paper in Circular 115; Farmers' Bulletin 601, "A New System of Cotton Culture and Its Application"; and Document 1130, "Single-Stalk Cotton Culture." Farmers' Bulletin 601 and the paper in Circular 115 explain the single-stalk system and give the results of experiments at Norfolk, Va., and in South Carolina. Document 1130 is an illustrated circular that shows how the vegetative branches are controlled and why larger yields are possible.

NOTE.—This bulletin will be of service generally in acquainting those who are interested in cotton growing with the several advantages to be gained through the application of single-stalk culture as compared with the more common methods. It will be particularly helpful to farmers and experimenters in locations similar to the San Antonio region.

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The period during which conditions are favorable for the setting of bolls in the region of San Antonio, Tex., is usually less than two months and frequently less than 30 days. In order to secure a good crop of cotton it is necessary, therefore, to practice the system of culture that will promote the production of the greatest number of bolls in the least time. For this reason the single-stalk system of culture has been looked upon as most nearly meeting the requirements of local conditions. To compare the merits of the common practice of wide spacing and the new single-stalk system, a series of tests was conducted in 1914 on the United States experiment farm at San Antonio. The results of these tests showed striking differences in favor of single-stalk culture.

In spite of the fact that the season was somewhat out of the ordinary, in that two months of excessively wet weather were followed by two months of drought, it was even more favorable for the production of cotton than ordinary seasons. Yields higher than the average were secured from rows grown according to the ordinary method of culture, even though the period during which bolls were set was shorter than normal. Whether the results in a normal season would have been more or less in favor of the single-stalk culture can not be definitely stated, but results of previous experiments indicate that even if the season had been normal the differences in the two methods of culture would have been comparatively the same.

COTTON PRODUCTION IN THE SAN ANTONIO REGION.

In the San Antonio region the development of cotton seedlings is frequently retarded because of the low temperatures that prevail often as late as the middle of May. As a result of exposure to low temperatures the plants are variously affected with the disorder known as leaf-cut,[1] some only slightly, others so seriously that the terminal buds abort. From the middle of May to early July the plants usually develop normally and constantly, June being especially favorable for their growth. Flowering commences from the first to the middle of June and reaches the maximum early in July. About the middle of July a drought usually ensues and continues until some time in August. This droughty condition causes the flowers to fall from the plants and only a very small percentage of the flowers that open in that period develop into bolls. By the end of July the plants cease to grow and very few flowers open. Rains usually fall during the latter part of August, and if the succeeding two months continue warm and the weevils are not numerous a "top crop" is sometimes produced.

[1] For a detailed explanation of the nature of this disorder, see the paper entitled "Leaf-Cut, or Tomosis, a Disorder of Cotton Seedlings," in Circular 120 of the Bureau of Plant Industry.

Usually the boll weevils do not appear in sufficient numbers to interfere materially with the setting of the crop before the first of July. During seasons of continued drought they are unable to reproduce rapidly enough to overcome the mortality caused by the falling of punctured squares and the action of the hot, dry atmosphere, and consequently they inflict little damage. In other words, drought is to a degree a beneficial factor in the production of a cotton crop in this region.[1] During more humid seasons, however, weevils infest practically all buds and squares by the middle of July.

From these facts it will be seen that cotton crops in the region of San Antonio must ordinarily be set within a month or a month and a half after flowering begins. Under the ordinary system of wide spacing, yields are usually rather low, averaging less than half a bale to the acre. During the season of 1914, however, nearly a bale to the acre was secured by the single-stalk system. Moreover, the bolls that produced this crop were set in less than 30 days.

The season of 1914 was exceptional only in the distribution of the rainfall, which tended to shorten the period of setting the crop. While the normal rainfall for April and May, respectively, is less than 3 inches, in 1914 more than 6 inches fell during each of these months. No rain fell from the first of June until the middle of August, so that a continued drought followed an extended period of rainfall.

PLAN OF TEST.

A plan of the field on which the ordinary system of wide spacing and the new single-stalk system of cotton culture were tested and compared in 1914 is shown in figure 1. In order to facilitate comparisons, the field was divided into four sections, which are designated as A, B, C, and D, respectively. All of the sections were planted with the same variety of cotton, Acala, a promising new type recently acclimatized from Mexico, which has given excellent results for several seasons at San Antonio.

In section A the two systems were compared in alternating rows; that is, single rows in which the plants were thinned early to 2 feet apart alternated with single rows in which the plants were thinned late and left less than 10 inches apart.

In section B 4-row blocks grown by the common system of culture alternated with 4-row blocks grown by the single-stalk system of culture.

In section C there were three blocks of five rows each. The plants in the five rows of each block were spaced to 6, 9, 12, 18, and 24 inches apart, respectively. The blocks were thinned on three different dates,

[1] See Bulletin 220 of the Bureau of Plant Industry, entitled "The Relation of Drought to Weevil Resistance in Cotton."

the first representing early, the second late, and the third very late thinning.

In section D the two systems were compared in alternate rows, the rows being planted 3, 4, 5, and 6 feet apart.

A guard row between sections A and B was not thinned at any time during the season.

Throughout this paper the rows representing the common practice of wide spacing are designated as wide-spaced rows and those representing the new system of close spacing are referred to as single-stalk rows.

PLANTING AND GERMINATION OF SEED.

It has been found desirable to plant from 25 to 30 pounds of seed to the acre if the rows are 4 feet apart, in order to secure a stand

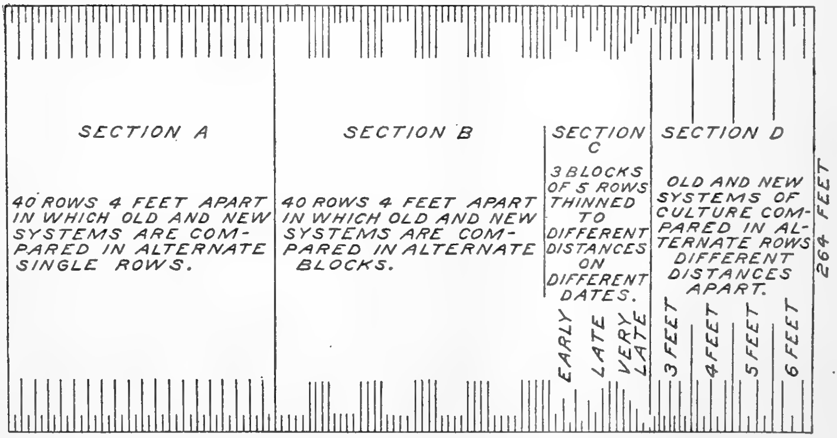

FIG. 1.—Plan of the field at San Antonio, Tex., in which the common system of wide spacing and the new single-stalk system of cotton culture were tested and compared in 1914.

in which the young plants become crowded sufficiently to restrict the development of the vegetative branches. Accordingly, the seed for the San Antonio test was sowed at the rate of about 30 pounds to the acre. The planting was done on April 14, with a 2-row planter.

Heavy rains and low temperatures rendered the conditions unfavorable for the germination of seed; but on account of the high rate of seeding a good stand was obtained. Nearly all rows had a short "skip" or two in which no plants appeared, but none of these skips were more than a few feet long, and it is believed that they had little effect on the yields. The skips were more numerous in section B than in any other section of the field, but were as frequent in single-stalk blocks as in wide-spaced blocks, and they therefore balanced the comparison of the two systems. Aside from these occasional skips, the stand was very satisfactory.

CHOPPING WIDE-SPACED ROWS.

In the region of San Antonio the general practice is to chop the plants when they are still very small, leaving one or two plants every 18 to 24 inches apart. This is usually done as soon as possible after germination, depending generally on weather conditions or when the choppers are best able to do the work, rather than on the stage of the plants' development. In the San Antonio test an attempt was made to approximate this practice in the wide-spaced rows. The plants were spaced to 2 feet, but owing to rain the chopping was delayed until May 6, 22 days after planting. At this time the plants were about 3 or 4 inches high and had one or two foliage leaves in addition to the seed leaves.

THINNING SINGLE-STALK ROWS.

In the single-stalk rows it was planned to leave the plants from 6 to 8 inches apart, and except in the short skips it was possible to secure the spacings desired. In order to have the spacing as accurate as possible and to leave the most promising plants the thinning was done by hand.

Care was exercised near the skips to leave the plants slightly closer together, in order that the effect of the open space might to a degree be overcome and that the development of vegetative branches might be prevented. Later observation showed, however, that one or two vegetative branches generally developed on plants next to skips or at the ends of rows.

The plants developed slowly during the cool, cloudy days of April and early May, so that it was late in May before they were in the proper condition for thinning. Because of continued rains the thinning was not done, however, until June 2. At this time the plants were about 12 inches high and had about eight full-grown leaves. On some of the most precocious plants fruiting branches had begun to develop. It is believed that had it been possible to do the thinning a week or 10 days earlier, when the plants had but five or six full-grown leaves and were only 8 or 10 inches high, it would have been more effective.

RESULTS OF THE TEST.

In comparing the wide-spaced and single-stalk systems of culture the following points were considered: Development of vegetative branches, rate of flowering, number of bolls set, number of locks in bolls, size of bolls, the form of rows, yields of seed cotton, and percentage and quality of lint.[1]

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[1] The writer was greatly assisted in securing the data at different times during the season by Messrs. Robert E. Kerr, James Taylor, H. Gregory McKeever, G. B. Gilbert, and G. W. R. Davidson. There was at all times close cooperation with the staff of the United States experiment farm at San Antonio.

While comparative yields comprise the most important consideration in such tests as long as the quality of the fiber is not injured in the system giving the highest yield, it is important to know what factors influence productiveness. Since the success of single-stalk culture depends primarily on the suppression of vegetative-branch development, it is important to know how conditions of climate and culture affect the growth of these branches. The rate of flowering and the setting of bolls are directly associated and have considerable bearing on the yields. The number of locks in the boll is not important so long as good yields are obtained, but a great reduction in the size of bolls would, of course, be undesirable under any system of culture. The distance to which plants spread between rows, especially near the ground, is important, since it may affect cultivation, picking, etc., and the distance apart rows should be planted may be limited by this feature. Data on all of these points were secured only in sections A and B, which included the largest part of the field. On some of the points, however, data were obtained from all sections.

DEVELOPMENT OF VEGETATIVE BRANCHES.

During warm and favorable spring weather in the region of San Antonio, cotton plants in wide-spaced rows develop five or six vegetative branches, but if the weather remains cool only two or three branches may develop. Though the development of vegetative branches was restricted more than usual by low temperatures in the season of 1914, it was possible by leaving the plants crowded in the rows to induce a further reduction in the number of branches. This can be clearly seen in Table I, which presents the average number of vegetative branches on plants in wide-spaced and single-stalk rows of Acala cotton in sections A and B. These averages represent the census from 25 consecutive plants in each of the rows.

TABLE I.—*Average number of vegetative branches on plants in wide-spaced and in single-stalk rows of Acala cotton in sections A and B, San Antonio, Tex., 1914.*

Alternate single rows (section A).				Alternate 4-row blocks (section B).			
Single-stalk rows.		Wide-spaced rows.		Single-stalk rows.		Wide-spaced rows.	
Row No.	Average of 25 plants.	Row No.	Average of 25 plants.	Row No.	Average of 25 plants.	Row No.	Average of 25 plants.
3	0.48	4	1.56	62	0.40	58	1.56
5	.56	6	1.60	63	.64	59	1.68
7	.50	8	1.72	64	.60	60	2.00
9	.40	10	1.64	65	.64	61	1.20

Table I shows that during the cool spring of 1914 an average of 1.6 vegetative branches developed on the wide-spaced plants, while the average on the single-stalk plants was 0.53 branch per plant. The range of averages in wide-spaced rows was from 1.2 to 2 branches per plant, while in single-stalk rows it was from 0.4 to 0.64 branch per plant.

FLOWERING RECORDS.

Beginning with June 17, when the first flowers appeared, a daily flower census was taken in sections A and B to compare the rate of flowering of wide-spaced and single-stalk rows. This was continued for 20 days. The results of the census are given in Table II.

In the first part of Table II, which represents the census in section A, it may be seen that for three days more flowers opened in the wide-spaced rows than in the single-stalk rows, while in the second part of the table, which represents the census taken in section B, this was true only on the first day that flowers opened. After the flowers in the single-stalk rows began to outnumber those in the wide-spaced rows the lead was maintained throughout the entire period. The increase in the number of flowers in single-stalk rows over that in the wide-spaced rows ranged from 30 to 204 per cent, the average for the 20-day period being 125.6 per cent in section A and 135 per cent in section B.

At the end of the 20-day flower census, July 6, the drought had become severe, and most of the flowers produced after that date failed to develop into bolls. Consequently the census for the entire field was not carried further, but was continued for 20 days longer on eight representative rows in each of sections A and B. None of the flowers opening after July 10 produced bolls, so these flowers had no part in increasing the yields of either single-stalk or wide-spaced rows. Their numbers are given, however, in Table III for four 10-day periods in order to show that the single-stalk rows continued to produce more flowers than the wide-spaced rows for the extended period.

Table III shows that at the end of 40 days 12,574 flowers had opened on 20 wide-spaced rows in section A, while 84.4 per cent more, or 23,189, had opened on 20 single-stalk rows. In section B 20 wide-spaced rows opened 13,725 flowers, while 20 single-stalk rows opened 78 per cent more, or 23,401 flowers.

TABLE II.—*Daily flower census of single-stalk and wide-spaced plants of Acala cotton at San Antonio, Tex.*

Row Nos.	June, 1914.														July, 1914.						Total.		
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	First 10 days.	Second 10 days.	For 20 days.
Alternate single rows (section A):																							
1, single stalk	0	0	0	0	1	0	0	7	3	11	25	52	49	76	107	148	247	173	212	226	22	1,315	1,337
2, wide spaced	0	0	0	2	2	0	2	10	10	12	25	17	25	38	66	85	116	83	101	119	38	675	713
3, single stalk	0	0	1	0	4	3	3	16	17	23	43	64	97	121	149	200	332	228	201	356	67	1,791	1,858
4, wide spaced	0	1	1	2	5	7	10	5	18	11	31	11	64	43	77	106	132	123	118	151	60	856	916
5, single stalk	0	0	0	1	1	6	16	28	41	27	67	68	110	124	200	236	323	317	312	289	120	2,046	2,166
6, wide spaced	0	0	0	1	4	4	12	5	14	12	24	34	48	69	90	110	138	146	130	141	52	930	982
7, single stalk	0	0	2	3	6	1	12	9	34	38	60	74	104	120	175	231	309	261	274	285	105	1,893	1,998
8, wide spaced	0	1	0	3	4	6	7	8	18	12	24	29	39	45	66	99	87	77	80	116	59	662	721
9, single stalk	0	0	0	2	8	12	25	17	47	87	64	90	146	143	207	237	332	288	294	269	198	2,070	2,268
10, wide spaced	0	0	0	6	2	7	12	13	23	30	38	37	57	63	101	131	144	144	132	128	93	975	1,068
11, single stalk	0	0	0	4	1	16	27	23	33	39	99	134	155	150	206	282	327	301	300	320	143	2,274	2,417
12, wide spaced	0	0	0	3	1	10	22	17	22	28	39	38	64	60	112	121	142	151	142	155	103	1,024	1,127
13, single stalk	0	1	1	8	8	19	33	27	58	86	110	87	172	189	200	324	325	243	250	279	241	2,179	2,420
14, wide spaced	0	1	3	4	4	12	30	15	25	22	41	40	43	72	69	126	121	98	99	121	116	830	946
15, single stalk	0	1	1	9	12	22	36	48	71	94	112	108	149	182	217	279	397	237	260	339	293	2,280	2,573
16, wide spaced	0	0	1	9	4	13	15	23	30	42	53	32	61	72	113	109	182	133	140	171	137	1,066	1,203
17, single stalk	0	0	1	2	6	13	26	31	44	51	93	96	124	159	169	224	301	221	262	235	174	1,884	2,058
18, wide spaced	1	0	4	3	2	7	15	12	17	20	45	43	51	52	93	122	129	116	120	124	81	895	976
19, single stalk	0	1	0	6	9	24	28	39	52	54	103	83	130	124	197	259	202	213	220	272	213	1,803	2,016
20, wide spaced	1	0	1	5	3	8	16	21	46	20	56	47	59	57	89	150	136	145	150	133	121	1,022	1,143
21, single stalk	0	0	0	4	8	25	32	31	46	49	82	103	134	153	197	216	305	243	260	223	195	1,916	2,111
22, wide spaced	0	1	1	3	1	5	14	14	32	18	31	29	49	53	72	93	118	109	107	111	89	772	861
23, single stalk	0	1	0	9	7	21	28	32	45	45	71	83	95	106	153	187	211	180	209	203	188	1,489	1,677
24, wide spaced	0	0	1	1	3	6	12	19	17	29	27	30	42	35	75	70	94	70	85	98	88	626	714
25, single stalk	0	0	1	4	8	19	43	42	61	71	101	110	145	173	190	226	292	226	250	249	249	1,962	2,211
26, wide spaced	1	0	0	2	2	12	20	14	35	25	47	47	54	55	91	110	133	76	90	127	111	830	941
27, single stalk	0	0	1	5	10	13	60	46	92	67	125	113	159	170	175	275	362	214	270	310	294	2,173	2,467
28, wide spaced	0	1	1	6	5	6	17	20	30	2	41	32	51	69	68	97	130	81	100	102	109	771	880
29, single stalk	0	0	1	7	4	22	32	55	34	50	94	104	137	159	150	282	305	234	267	282	255	2,014	2,269
30, wide spaced	0	1	0	8	10	15	15	23	17	19	31	45	51	68	82	104	118	125	132	131	108	887	995
31, single stalk	0	1	1	7	5	13	29	37	58	72	70	104	107	118	145	197	241	201	260	190	223	1,633	1,856
32, wide spaced	0	0	1	0	2	3	9	11	18	18	23	25	27	30	46	112	73	75	81	86	62	578	640

33, single stalk	0	0	3	6	3	14	25	35	57	49	78	71	128	100	129	149	267	176	200	224	192	1,522	1,714
34, wide spaced	0	1	1	3	4	6	16	20	29	18	52	27	48	52	75	55	161	89	94	120	98	773	871
35, single stalk	0	0	0	4	10	22	23	29	47	63	71	83	93	98	128	144	352	175	181	250	198	1,575	1,675
36, wide spaced	0	0	1	2	3	8	20	15	23	14	26	35	44	40	65	60	91	83	79	120	86	643	739
37, single stalk	0	0	0	0	5	10	25	19	39	41	66	67	96	93	103	135	194	103	112	178	139	1,147	1,286
38, wide spaced	0	0	0	0	2	5	9	15	18	14	24	35	29	30	36	55	76	39	52	83	63	459	522
39, single stalk	0	0	0	5	8	8	37	33	40	34	64	64	99	84	110	184	223	178	200	219	165	1,425	1,590
40, wide spaced	0	0	2	3	6	10	14	16	23	27	24	28	49	64	70	86	101	78	82	110	101	692	793
Total, wide-spaced rows	3	7	18	66	69	150	287	296	465	414	702	661	955	1,067	1,556	2,001	2,422	2,041	2,114	2,447	1,775	15,966	17,741
Total, single-stalk rows	0	5	13	86	124	283	540	604	919	1,051	1,598	1,758	2,429	2,642	3,307	4,415	5,847	4,412	4,785	5,198	3,624	36,391	40,015
Increase of single-stalk rows, per cent	....	−29	−28	30	80	89	88	104	98	154	127	166	154	147	112	120	141	116	126	113	105	128	125.6
Alternate 4-row blocks (section B):																							
42, wide spaced	0	0	2	2	9	11	20	19	18	17	28	36	41	32	49	83	93	70	78	99	98	609	707
43, wide spaced	0	0	1	3	5	8	11	14	13	13	24	37	24	33	48	65	94	61	65	98	68	549	617
44, wide spaced	0	0	0	3	2	3	5	9	16	13	18	13	18	20	34	52	75	45	52	77	51	404	455
45, wide spaced	0	0	0	1	3	2	7	12	8	13	19	14	24	23	32	47	66	44	56	48	46	373	419
46, single stalk	0	0	2	3	6	18	23	31	42	55	69	78	102	80	119	157	189	149	155	187	180	1,285	1,465
47, single stalk	0	0	5	2	9	11	34	24	39	56	84	83	130	143	151	201	293	170	212	215	180	1,682	1,862
48, single stalk	0	0	2	2	6	22	22	35	33	57	81	85	106	108	147	215	218	200	205	254	179	1,619	1,798
49, single stalk	0	0	0	5	3	11	26	29	30	31	89	88	114	103	136	177	248	159	196	217	135	1,527	1,662
50, wide spaced	0	0	1	4	7	8	19	16	17	23	13	30	34	40	72	71	87	74	92	106	95	619	714
51, wide spaced	0	0	2	2	3	11	8	19	24	19	31	38	38	57	76	85	122	79	109	115	88	750	838
52, wide spaced	0	0	1	3	1	8	6	13	14	13	25	23	37	46	50	59	68	71	78	89	59	546	605
53, wide spaced	1	0	1	1	4	4	9	18	13	13	24	27	36	37	57	71	94	83	71	103	64	603	667
54, single stalk	1	0	3	6	7	16	40	40	54	64	90	100	134	120	159	220	267	162	192	214	231	1,658	1,889
55, single stalk	0	0	2	4	9	20	45	46	73	59	119	83	114	134	148	216	267	211	151	239	258	1,682	1,940
56, single stalk	0	0	0	5	5	16	24	46	73	51	105	96	130	136	152	193	280	226	196	294	220	1,808	2,028
57, single stalk	0	0	1	1	2	6	12	27	43	53	80	60	84	81	134	168	190	158	152	194	145	1,301	1,446
58, wide spaced	1	2	3	5	8	13	12	25	36	26	45	31	48	61	104	84	111	116	100	136	131	836	967
59, wide spaced	2	1	3	4	8	15	19	24	42	21	56	26	77	65	98	115	144	117	107	133	139	938	1,077
60, wide spaced	1	1	1	2	4	13	13	16	27	20	37	38	48	66	83	109	87	113	110	132	98	823	921
61, wide spaced	0	0	1	0	2	3	10	15	21	16	27	22	39	37	57	77	93	76	73	104	68	605	673
62, single stalk	1	0	5	10	10	24	73	48	56	87	90	124	137	195	206	280	276	212	218	275	314	2,013	2,327
63, single stalk	0	1	4	12	23	30	31	52	48	71	104	97	147	175	187	249	280	268	247	248	272	2,002	2,274
64, single stalk	0	2	2	11	11	29	34	44	48	70	102	110	161	180	237	196	333	217	218	248	251	2,002	2,253
65, single stalk	0	0	1	5	11	33	61	34	58	99	92	140	169	185	247	286	365	233	335	293	302	2,345	2,647

TABLE II.—*Daily flower census of single-stalk and wide-spaced plants of Acala cotton at San Antonio, Tex.*—Continued.

Row Nos.	June, 1914.														July, 1914.						Total.		
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	First 10 days.	Second 10 days.	For 20 days.
Alternate 4-row blocks (section B)—Continued.																							
66, wide spaced	2	2	6	8	12	18	31	22	36	35	66	80	91	122	132	139	170	137	145	193	172	1,275	1,447
67, wide spaced	0	0	2	4	8	17	24	22	26	31	61	41	57	67	90	124	146	113	135	142	134	976	1,110
68, wide spaced	0	0	0	1	5	12	10	19	36	33	31	30	56	73	86	116	110	99	131	118	116	850	966
69, wide spaced	1	1	2	2	7	21	17	32	32	20	44	44	73	79	88	97	155	114	161	141	135	996	1,131
70, single stalk	0	0	3	11	11	30	44	67	62	75	109	121	152	188	211	224	346	289	257	324	303	2,221	2,524
71, single stalk	0	1	2	14	10	35	48	54	56	91	129	119	190	208	224	261	297	273	255	271	311	2,227	2,538
72, single stalk	0	0	0	1	18	17	35	29	54	58	100	77	142	157	208	231	333	219	231	275	212	1,973	2,185
73, single stalk	0	2	2	8	20	33	51	57	57	82	126	165	165	221	253	300	360	291	336	277	312	2,494	2,806
74, wide spaced	0	1	5	6	17	19	31	27	43	35	65	41	77	81	118	139	172	147	138	181	184	1,159	1,343
75, wide spaced	0	0	0	9	10	16	20	32	45	45	70	43	63	81	105	133	154	149	118	173	177	1,089	1,266
76, wide spaced	1	4	3	6	6	23	23	21	34	25	39	62	78	91	120	132	187	127	162	185	146	1,183	1,329
77, wide spaced	0	0	0	6	9	18	18	18	35	41	38	49	62	81	93	113	137	94	140	135	145	942	1,087
78, single stalk	0	4	4	5	14	28	54	69	65	89	116	124	169	188	236	224	297	225	232	257	332	2,068	2,400
79, single stalk	0	2	2	4	14	29	40	47	53	70	137	108	146	207	194	194	302	286	332	264	261	2,170	2,431
80, single stalk	0	2	4	9	16	30	38	68	53	90	126	156	179	196	246	241	250	281	222	239	310	2,136	2,446
81, single stalk	0	2	1	9	9	25	39	76	49	76	85	91	119	160	188	210	364	208	245	279	285	1,949	2,234
Total, wide-spaced rows	9	12	34	72	130	243	313	393	536	472	761	725	1,021	1,192	1,592	1,911	2,365	1,929	2,121	2,508	2,214	16,125	18,339
Total, single-stalk rows	2	16	45	127	214	463	774	923	1,046	1,384	2,033	2,105	2,790	3,165	3,783	4,443	5,755	4,437	4,587	5,064	4,993	38,162	43,155
Increase of single-stalk rows, per cent	−77	33	32	51	65	90	147	135	95	193	162	204	173	165	138	132	143	130	116	102	125	137	135

TABLE III.—*Flower census by 10-day periods in wide-spaced and single-stalk rows of Acala cotton in sections A and B, San Antonio, Tex., 1914.*

Row No.	Total flowers in alternate single rows (section A).					Row No.	Total flowers in alternate 4-row blocks (section B).				
	First 10 days, June 17–26.	Second 10 days, June 27–July 6.	Third 10 days, July 7–16.	Fourth 10 days, July 17–26.	For 40 days, June 17–July 26.		First 10 days, June 17–26.	Second 10 days, June 27–July 6.	Third 10 days, July 7–16.	Fourth 10 days, July 17–26.	For 40 days, June 17–July 26.
3, single stalk	67	1,791	2,222	1,620	5,700	58, wide spaced	131	836	1,533	1,289	3,789
4, wide spaced	60	856	1,231	1,079	3,226	59, wide spaced	139	938	1,455	1,215	3,747
5, single stalk	120	2,046	2,110	1,686	5,962	60, wide spaced	98	823	1,438	1,231	3,590
6, wide spaced	52	930	1,253	1,147	3,382	61, wide spaced	68	605	1,078	848	2,599
7, single stalk	105	1,893	2,064	1,553	5,615	62, single stalk	314	2,013	2,265	1,316	5,908
8, wide spaced	59	662	986	833	2,540	63, single stalk	272	2,002	2,373	1,098	5,745
9, single stalk	198	2,070	2,204	1,440	5,912	64, single stalk	251	2,002	2,292	947	5,492
10, wide spaced	93	975	1,375	983	3,426	65, single stalk	302	2,345	2,523	1,086	6,256
Total, single stalk	490	7,800	8,600	6,299	23,189	Total, wide spaced	436	3,202	5,504	4,583	13,725
Total, wide spaced	264	3,423	4,845	4,042	12,574	Total, single stalk	1,139	8,362	9,453	4,447	23,401
Increase, single stalk, per cent	86	128	78	56	84.4	Increase, single stalk, per cent	161	161	72	−3	87

NUMBER OF BOLLS SET.

To compare the efficiency of single-stalk and wide-spaced rows in the production of bolls, the total number of bolls set in rows 3 to 10 in section A and in rows 58 to 65 in section B were recorded. The results of the census are presented in Table IV.

TABLE IV.—*Bolls matured on wide-spaced and single-stalk rows of Acala cotton, 264 feet long, San Antonio, Tex., 1914.*

Row No. (section A).	Plants in row.	Bolls matured on row.	Bolls per plant.	Row No. (section B).	Plants in row.	Bolls matured on row.	Bolls per plant.
3, single stalk	350	2,021	5.7	58, wide spaced	100	1,129	11.3
4, wide spaced	120	750	6.2	59, wide spaced	98	1,070	10.9
5, single stalk	405	2,086	5.1	60, wide spaced	110	999	9.0
6, wide spaced	124	941	7.6	61, wide spaced	109	731	6.7
7, single stalk	377	2,120	5.1	62, single stalk	276	2,001	7.2
8, wide spaced	95	806	8.5	63, single stalk	303	1,669	5.5
9, single stalk	387	2,203	5.8	64, single stalk	290	1,465	5.0
10, wide spaced	108	893	8.3	65, single stalk	451	1,889	4.2
Average, single stalk	380	2,108	5.42	Average, single stalk	332	1,756	5.47
Average, wide spaced	112	848	7.65	Average, wide spaced	104	982	8.6
Increase, single stalk, per cent.	232	149	....	Increase, single stalk, per cent.	222	78	....

Table IV shows that plants in single-stalk rows set an average of five or six bolls each and those in wide-spaced rows about eight bolls, but the single-stalk rows contained about 225 per cent more plants than the wide-spaced rows, so that the total number of bolls set in single-stalk rows was greater. The single-stalk rows in section A set 149 per cent more bolls than the adjoining wide-spaced rows. In section B the single-stalk rows set 78 per cent more bolls than the wide-spaced rows. The increase of inside rows, which approach most nearly the conditions of uniform field culture, was 47 per cent in favor of single-stalk rows. As will be shown later, the difference in yields from these rows favored single-stalk culture in about the proportion indicated by the number of bolls set.

NUMBERS OF LOCKS IN THE BOLLS.

Another census was made of bolls in single-stalk and wide-spaced rows to determine the percentages of 3, 4, and 5 locked bolls produced under the different systems of culture. Although the number of locks, or carpels, is always a variable character, the relative number of 3, 4, and 5 locked bolls is somewhat altered by different conditions of culture or climate. For instance, under irrigation a higher percentage of 5-locked bolls is produced than under dry-land culture.

In previous years it has been found that a lower percentage of 5-locked bolls was produced under the single-stalk system of culture than under the wide-spacing system, and the census taken at San Antonio in 1914 corroborates these former results. To determine the percentages of bolls with 3, 4, and 5 locks, a count of at least 300 bolls was taken in each row and the number of locks recorded. It was, of course, possible to secure the required number of bolls in less row space in the single-stalk rows than in the wide-spaced rows. The percentages of 3, 4, and 5 locked bolls in sections A and B are presented in Table V.

TABLE V.—*Ratio of 3-locked, 4-locked, and 5-locked bolls in rows of Acala cotton in sections A and B grown under the wide-spaced and single-stalk systems of culture, San Antonio, Tex., 1914.*

Row No.	Wide-spaced rows.					Single-stalk rows.				
	Locks in bolls—				5-locked bolls.	Locks in bolls—				5-locked bolls.
	3	4	5	Total.		3	4	5	Total.	
Alternate single rows (section A):					*Per cent.*					*Per cent.*
3							202	165	367	45.0
4		91	230	321	71.8					
5						5	193	188	386	48.7
6		168	201	369	54.5					
7						3	199	162	364	44.5
8	2	156	199	357	55.7					
9						2	200	155	357	43.4
10	1	149	202	352	57.4					
Alternate 4-row blocks (section B):										
58		154	181	335	54.0					
59		142	171	313	54.6					
60		161	207	368	56.2					
61		192	169	361	46.8					
62							171	133	304	43.7
63							186	146	332	44.0
64							180	120	300	40.0
65							130	202	332	60.8
Total	3	1,213	1,560	2,776		10	1,461	1,271	2,742	
Per cent	0.08	43.7	56.2	100	56.2	0.4	53.3	46.3	100	46.3

Table V shows that the range in percentage of 5-locked bolls in wide-spaced rows was from 47 to 72, with an average of 56, while in single-stalk rows the range was from 43 to 61 per cent, with an average of 46 per cent.

The production of a higher percentage of 4-locked bolls in single-stalk rows need not be considered an undesirable feature, since 4-locked bolls are more readily picked and the lint in them is fully as good as that in 5-locked bolls. The number of 3-locked bolls is insignificant.

SIZE OF BOLLS.

A comparison of the size of bolls was obtained by weighing 25 4-locked and 25 5-locked bolls from wide-spaced and single-stalk rows. The 4-locked bolls from single-stalk and wide-spaced rows weighed 5.04 and 5.32 grams, respectively, a difference of 0.28 gram. The weights of the 5-locked bolls were 5.64 and 6.2 grams for single-stalk and wide-spaced rows, respectively, the difference being 0.56 gram. Bolls from wide-spaced rows in both 4 and 5 locked samples weighed slightly more than those from single-stalk rows. In other words, 19 4-locked bolls from single-stalk rows have the same weight as 18 4-locked bolls from wide-spaced rows, and 11 5-locked bolls from single-stalk rows equal 10 5-locked bolls from wide-spaced rows. Five-locked bolls weighed from 0.6 to 0.8 of a gram more than 4-locked bolls. A slight reduction in the size of the bolls may be looked upon as a necessary consequence of producing a larger crop under the conditions of drought that ruled during the period of development of the bolls.

FORMS OF ROWS.

It has been previously shown that plants in wide-spaced rows developed more vegetative branches at the base than plants in single-stalk rows. The vegetative branches spread out from the base of the plants in the wide-spaced rows, forming rows that in cross section were broader near the ground than near the top of the plants.

Few plants in single-stalk rows had vegetative branches, so that the plants were made up of main stalks only. These grew erect and formed a narrow hedgelike row early in the season. Later, however, as the plants became taller, they leaned to one side or the other, making the rows broader at the top than near the ground. A cross section of a single-stalk row resembled an inverted cone or pyramid. This feature is clearly illustrated in Plate I, which shows an end view of a single-stalk row of Blackseed cotton. The contrast in form between the single-stalk and the wide-spaced rows is illustrated in Plates III and IV. At the end of the season the plants in the single-stalk rows were more than 6 inches taller than those in the wide-spaced rows, being 3.96 and 3.36 feet in height, respectively.

It was found possible to cultivate close to the plants in single-stalk rows without injury to the stalks. On the other hand, it was difficult to cultivate so close to the plants in wide-spaced rows without injuring the vegetative branches and the stalks.

All fruit was borne on the lower half of the plants in both kinds of rows, as may be seen in Plates I, III, IV, and in figure 1 of Plate V. As previously stated, the drought caused the shedding of all the bolls and flowers that would have developed after July 10. The bare stalks that appear above the fruited portions of the plants represent the growth made after the middle of July. Until the August rains relatively little growth was made, but after these rains the growth was very rapid. It was after this period of rapid growth that the taller plants in the single-stalk rows began to lean to one side or the other, resulting in the form of row shown in Plate I.

YIELDS FROM SECTIONS A AND B.

It has been shown that, compared with wide-spaced rows, the single-stalk rows in sections A and B showed far less vegetative-branch development, and that the plants grew to a greater height, thus facilitating cultivation between the rows; they produced flowers in greater abundance, and they set more bolls of about the same size as the others, though a higher percentage contained four instead of five locks.

It now remains to be shown how the two systems of culture compared from the standpoint of yield, which is the most important consideration, provided that the quality of the lint is not affected. The yields are recorded in Table VI.

Table VI shows that in section A, in which wide-spaced and single-stalk rows were compared in alternate rows, the yields from wide-spaced rows ranged from 9 to 14.4 pounds, while in single-stalk rows the range was from 17.6 to 31 pounds, the lowest yield from the single-stalk rows being 22 per cent greater than the highest yield from wide-spaced rows. These results are shown graphically in figure 2. The increase in the total yield of the single-stalk rows over the adjoining wide-spaced rows ranged from 63 to 227 per cent, with an average of 125.5 per cent. (See Pl. II.)

At the time the first picking was made, on August 11, 31 per cent of the total crop from the wide-spaced rows was picked, as compared with only 26 per cent of the crop from the single-stalk rows. In spite of this fact, the first picking from the single-stalk rows yielded 88 per cent more seed cotton than the wide-spaced rows. The second picking was made on September 8, when the yield obtained from single-stalk rows was 144 per cent more than that from wide-spaced rows.

TABLE VI.—*Yields from wide-spaced and single-stalk rows of Acala cotton in sections A and B, San Antonio, Tex., 1914.*

[Rows 4.1 feet apart, 264 feet long.]

Row No.	Number of plants.	Alternate single rows (section A). First picking, Aug. 11.	Alternate single rows (section A). Second picking, Sept. 8.	Alternate single rows (section A). Total picking.	Increase of single-stalk rows over wide-spaced rows.	Row No.	Number of plants.	Alternate 4-row blocks (section B). First picking, Aug. 11.	Alternate 4-row blocks (section B). Second picking, Sept. 8.	Alternate 4-row blocks (section B). Total picking.	Increase of single-stalk rows over wide-spaced rows.
		Lbs.	*Lbs.*	*Lbs.*	*Pr. ct.*			*Lbs.*	*Lbs.*	*Lbs.*	*Pr. ct.*
1, single stalk...	404	3.3	27.5	30.8	161	42, wide spaced....	100	2.8	8.9	11.7	....
2, wide spaced..	109	2.8	9.0	11.8	....	43, wide spaced....	104	3.2	11.8	15.0	....
3, single stalk...	350	6.1	21.0	27.1	153	44, wide spaced....	103	2.1	10.5	12.6	....
4, wide spaced..	120	3.3	7.4	10.7	....	45, wide spaced....	83	2.6	7.8	10.4	....
5, single stalk...	405	6.9	21.8	28.7	109	46, single stalk.....	233	6.1	15.4	21.5	84
6, wide spaced..	124	3.8	9.9	13.7	....	47, single stalk.....	320	7.5	14.4	21.9	53
7, single stalk...	377	7.2	22.2	29.4	227	48, single stalk.....	258	7.4	14.8	22.2	51
8, wide spaced..	95	3.1	5.9	9.0	....	49, single stalk.....	410	7.0	13.8	20.8	100
9, single stalk...	387	7.4	21.7	29.1	122	50, wide spaced....	100	4.0	8.3	12.3	....
10, wide spaced.	108	4.6	8.5	13.1	....	51, wide spaced....	113	4.4	12.0	16.4	....
11, single stalk..	361	8.6	22.4	31.0	142	52, wide spaced....	100	3.4	9.4	12.8	....
12, wide spaced.	121	4.9	7.9	12.8	....	53, wide spaced....	93	3.5	9.9	13.4	....
13, single stalk..	362	10.2	20.8	31.0	161	54, single stalk.....	362	8.0	14.3	22.3	81
14, wide spaced.	102	4.1	7.8	11.9	....	55, single stalk.....	271	8.7	12.5	21.2	29
15, single stalk..	351	10.0	19.9	29.9	114	56, single stalk.....	388	8.4	12.1	20.5	60
16, wide spaced.	131	5.4	8.6	14.0	....	57, single stalk.....	284	6.1	11.8	17.9	34
17, single stalk..	350	7.0	19.6	26.6	96	58, wide spaced....	100	6.0	8.0	14.0	....
18, wide spaced.	105	4.2	9.4	13.6	....	59, wide spaced....	98	6.0	9.6	15.6	....
19, single stalk..	286	8.9	19.5	28.4	97	60, wide spaced....	110	5.5	8.8	14.3	....
20, wide spaced.	138	4.8	9.6	14.4	....	61, wide spaced....	109	3.5	6.8	10.3	....
21, single stalk..	342	7.1	19.3	26.4	126	62, single stalk.....	276	10.0	14.6	24.6	76
22, wide spaced.	100	2.9	8.8	11.7	....	63, single stalk.....	303	10.3	8.4	18.7	20
23, single stalk..	283	4.9	18.3	23.2	117	64, single stalk.....	290	10.6	6.6	17.2	20
24, wide spaced.	100	3.6	7.1	10.7	....	65, single stalk.....	451	11.0	11.6	22.6	119
25, single stalk..	380	8.4	14.1	22.5	63	66, wide spaced....	114	7.5	6.3	13.8	....
26, wide spaced.	132	4.4	9.4	13.8	....	67, wide spaced....	107	6.8	7.8	14.6	....
27, single stalk..	396	8.9	21.6	30.5	135	68, wide spaced....	128	5.2	8.3	13.5	....
28, wide spaced.	121	3.6	9.4	13.0	....	69, wide spaced....	133	6.4	6.7	13.1	....
29, single stalk..	416	7.6	21.3	28.9	121	70, single stalk.....	370	11.1	12.3	23.4	69
30, wide spaced.	127	4.3	8.8	13.1	....	71, single stalk.....	399	13.3	9.0	22.3	53
31, single stalk..	319	6.9	19.5	26.4	161	72, single stalk.....	413	11.4	9.3	20.7	53
32, wide spaced.	103	2.8	7.3	10.1	....	73, single stalk.....	431	13.4	11.8	25.2	92
33, single stalk..	354	5.3	20.6	25.9	101	74, wide spaced....	126	6.4	6.3	12.7	....
34, wide spaced.	131	3.7	9.2	12.9	....	75, wide spaced....	128	7.3	9.0	16.3	....
35, single stalk..	292	......	[a]20.9	20.9	95	76, wide spaced....	136	8.6	8.4	17.0	....
36, wide spaced.	110	......	[a]10.7	10.7	....	77, wide spaced....	106	6.9	6.1	13.0	....
37, single stalk..	295	......	[a]17.6	17.6	83	78, single stalk.....	409	12.2	10.5	22.7	79
38, wide spaced.	100	......	[a]9.6	9.6	....	79, single stalk.....	348	11.5	7.3	18.8	15
39, single stalk..	268	......	[a]21.6	21.6	90	80, single stalk.....	389	10.9	9.5	20.4	20
40, wide spaced.	122	......	[a]11.4	11.4	....	81, single stalk.....	271	12.6	8.3	20.9	60
Total, single stalk..	6,978	124.7	351.1	535.9	....	Total, wide spaced......	2,191	102.1	170.7	272.8	....
Total, wide spaced....	2,299	66.3	144.0	242.0	....	Total, single stalk........	6,840	197.5	228.3	425.8	....
Average, single stalk....	349	7.3	20.65	26.8	....	Average, wide spaced........	110	5.1	8.5	13.64	....
Average, wide spaced......	115	3.9	8.47	12.1	....	Average, single stalk..........	342	9.87	11.4	21.3	....
Open crop, single stalk, per cent..........	......	26.2	73.8	100.0	....	Open crop, wide spaced, per cent..............	......	37.4	62.6	100.0	....
Open crop, wide spaced, per cent..........	......	31.5	68.5	100.0	....	Open crop, single stalk, per cent...	......	46.4	53.6	100.0	....
Acre yield, single stalk, pounds.......	......	......	......	1071	....	Acre yield, wide spaced, pounds..	......	......	......	546	....
Acre yield, wide spaced, pounds	......	......	......	484	....	Acre yield, single stalk, pounds....	......	......	......	852	....
Increase, single stalk, per cent........	......	88	144	121.5	121.5	Increase, single stalk, per cent...	......	98.5	33.7	56.1	56.1

[a] Not included in total.

The yields from the alternate blocks of section B shown in Table VI represent more nearly what may be expected under field conditions. The results are similar to those obtained from the alternate rows in section A, though the differences are less extreme. The total yields from the wide-spaced rows ranged from 10.3 to 17 pounds and those from the single-stalk rows from 17.2 to 25.2 pounds, the minimum yield from the single-stalk rows being practically the same as the maximum yield from the wide-spaced rows. These results are presented graphically in figure 3. At the time the first picking was made, August 11, 37 per cent of the crop in the wide-spaced rows was

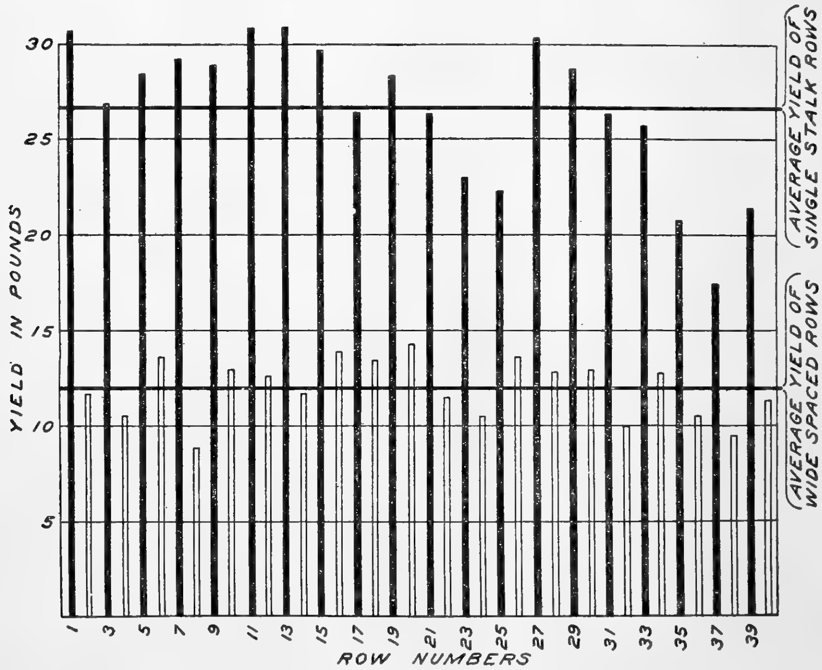


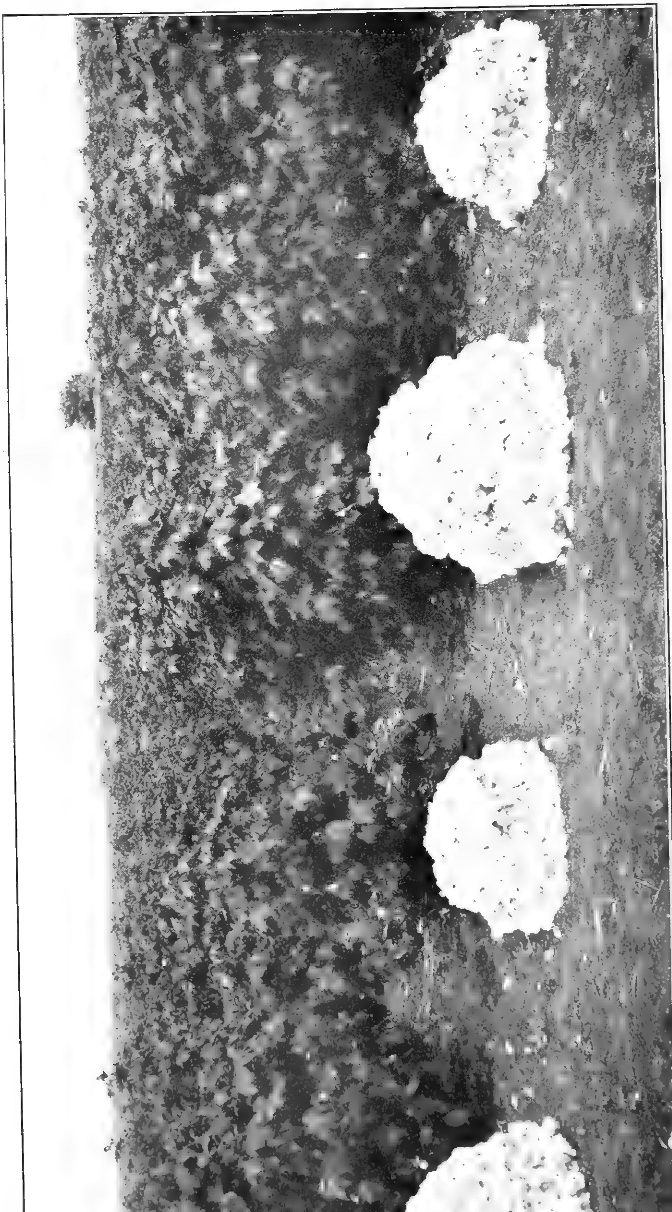
FIG. 2.—Diagram showing the yields from single-stalk and wide-spaced rows of Acala cotton in section A, San Antonio, Tex., in 1914. Wide-spaced rows represented by double lines, single-stalk rows by heavy lines.

harvested, as compared with 47 per cent of the crop in the single-stalk rows, the latter yielding 93 per cent more seed cotton. The second picking from the single-stalk rows was 33.7 per cent greater than that from the wide-spaced rows. The increase in the total yield of individual rows in any single-stalk block over the corresponding rows in the preceding wide-spaced block ranged from 15 to 119 per cent, the average being 56.1 per cent.

Reference to figure 3 will show that in most cases the inside rows of wide-spaced blocks and the outside rows of single-stalk blocks yielded more than the other two rows of the same blocks. This

END VIEW OF THE SINGLE-STALK ROW OF BLACKSEED COTTON SHOWN IN PLATE III, FIGURE 1, IN WHICH THE CORRESPONDING PLANTS ARE DESIGNATED BY THE SAME LETTERS USED HERE.

This illustrates the form of row common to the single-stalk system of culture. Note how the plants lean to one side or the other.



ALTERNATING SINGLE-STALK AND WIDE-SPACED ROWS OF ACALA COTTON, WITH THE TOTAL AMOUNT OF SEED COTTON TAKEN FROM THEM AT THE ENDS OF THE ROWS.

Note the greater height and the more erect habit of growth of the single-stalk rows, which are represented by the larger piles of cotton.

FIG. 1.—SIDE VIEW OF THE SINGLE-STALK ROW OF BLACKSEED COTTON SHOWN IN PLATE I, THE CORRESPONDING PLANTS BEING DESIGNATED BY THE SAME LETTERS.

These 11 plants, with only 2 vegetative branches, produced a total of 88 bolls. Most of the leaves have been removed to show the branching habit and slender form of the plants. Note the lack of crowding. Compare with Plate III, figure 2. (The plants were 8 feet from the camera when photographed.)

FIG. 2.—SIDE VIEW OF THREE PLANTS IN A WIDE-SPACED ROW OF BLACKSEED COTTON.

These 3 plants bore 11 vegetative branches and produced a total of 67 bolls. They cover the same extent of row space as those in Plate III, figure 1. Most of the leaves have been removed to show the branching habit and bushy form of the plants. (The plants were 8 feet from the camera when photographed.)

FIG. 1.—ELEVEN PLANTS IN A SINGLE-STALK ROW OF ACALA COTTON WITH A TOTAL OF 3 VEGETATIVE BRANCHES AND 59 BOLLS.

This shows a single-stalk row as it should look when properly spaced. Note the absence of vegetative branches and the uniform position of the fruit. Compare with Plate IV, figure 2. (The plants were 8 feet from the camera when photographed.)

FIG. 2.—THREE PLANTS IN A WIDE-SPACED ROW OF ACALA COTTON WITH A TOTAL OF 8 VEGETATIVE BRANCHES AND 33 BOLLS.

Note the development of vegetative branches and the irregular placement of the fruit. Compare with Plate IV, figure 1. (The plants were 8 feet from the camera when photographed.)

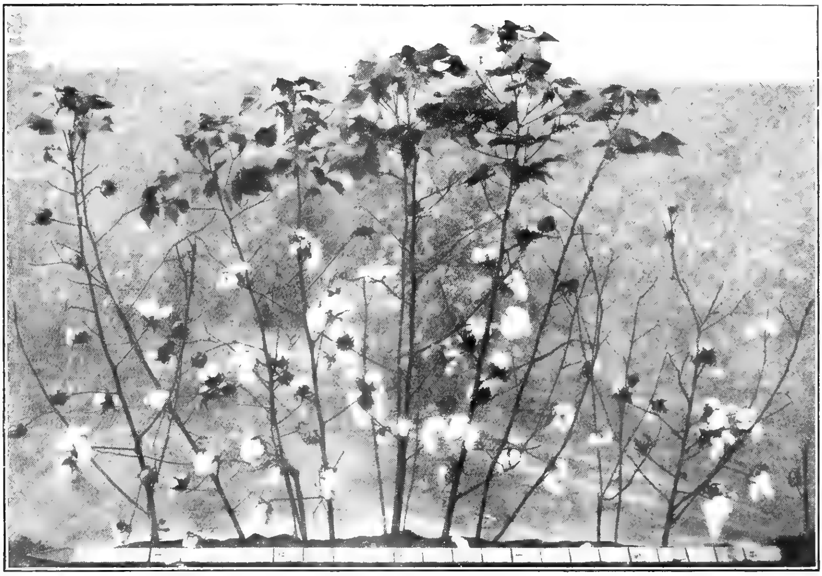


FIG. 1.—SIXTEEN PLANTS IN AN UNTHINNED ROW OF ACALA COTTON WITH 10 VEGETATIVE BRANCHES AND 70 BOLLS.

Seven of the 10 vegetative branches were produced on the two end plants of the section, adjacent to open spaces in the row. This illustrates the effectiveness of crowding to suppress the development of vegetative branches. But note the smaller plants, which produced no bolls. This probably is due to the suppression or abortion of fruiting branches, brought on by the overcrowded condition of the row during its fruiting period. Single-stalk culture aims to avoid such a condition. Compare with Plate III, figure 1, and Plate IV, figure 1. (The plants were 8 feet from the camera when photographed.)

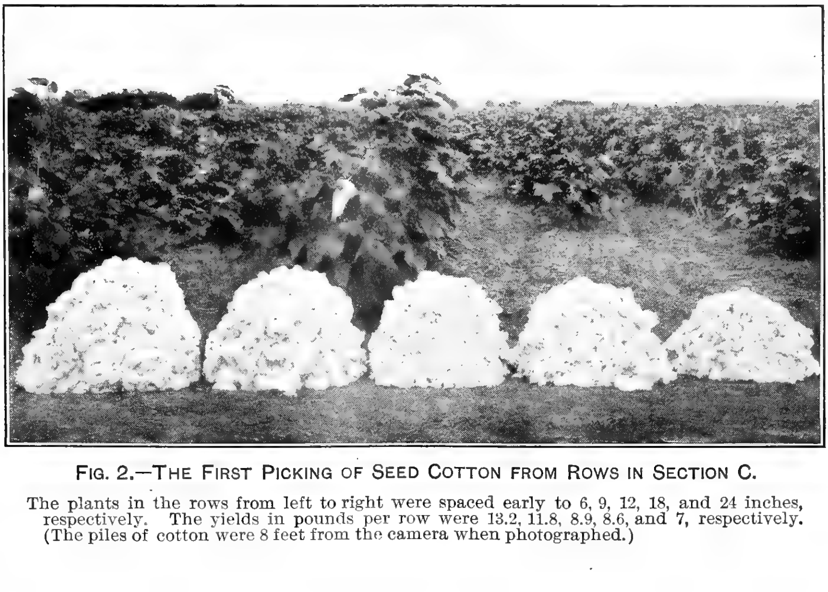


FIG. 2.—THE FIRST PICKING OF SEED COTTON FROM ROWS IN SECTION C.

The plants in the rows from left to right were spaced early to 6, 9, 12, 18, and 24 inches, respectively. The yields in pounds per row were 13.2, 11.8, 8.9, 8.6, and 7, respectively. (The piles of cotton were 8 feet from the camera when photographed.)

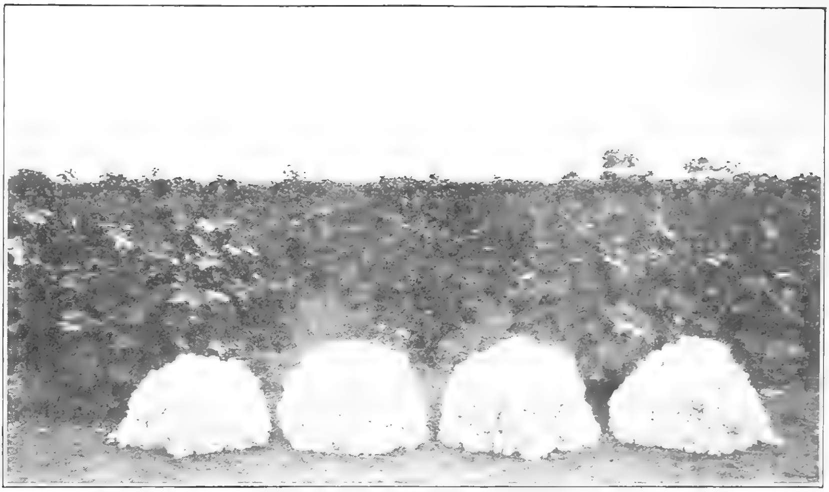


FIG. 1.—TOTAL YIELDS FROM FOUR CONSECUTIVE WIDE-SPACED ROWS OF ACALA COTTON IN SECTION B, NUMBERED FROM LEFT TO RIGHT 58, 59, 60, AND 61, RESPECTIVELY.

The yields in pounds per row were 14, 15.6, 14.3, and 10.3, respectively. Note the greater yields from the inside rows. Compare with Plate VI, figure 2. (The piles of cotton were 8 feet from the camera when photographed.)

FIG. 2.—TOTAL YIELDS FROM FOUR CONSECUTIVE SINGLE-STALK ROWS OF ACALA COTTON IN SECTION B, NUMBERED FROM RIGHT TO LEFT 62, 63, 64, AND 65, RESPECTIVELY.

The yields in pounds per row were 21.6, 18.7, 17.2, and 22.6, respectively. Note the greater yields from the outside rows. Compare with Plate VI, figure 1. (The piles of cotton were 8 feet from the camera when photographed.)

point is illustrated further in Plate VI, figures 1 and 2, which present yields from rows in wide-spaced and single-stalk blocks, respectively.

General observations made throughout the season, comparing the development of single-stalk and wide-spaced rows, showed how the above conditions might be accounted for. Plants in the single-stalk rows seemed sooner to take advantage of any inter-row or inter-plant soil space and to more readily utilize the available soil moisture. On this account plants in single-stalk rows may have gained an advantage over adjoining wide-spaced rows early in the season and to a degree have invaded the soil that would otherwise have been utilized by the wide-spaced rows. This advantage would be cumulative, and as the season progressed the plants in the single-stalk rows appeared to show distinct superiority in this respect. This may also account

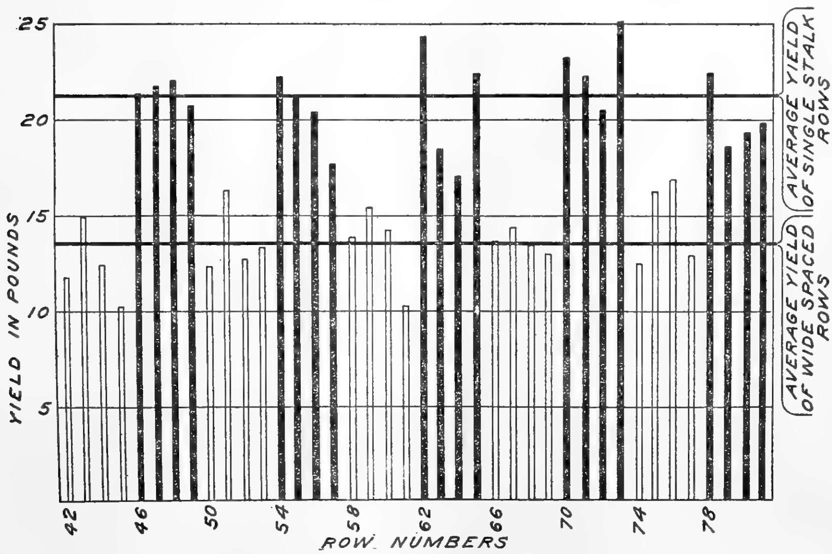


FIG. 3.—Diagram showing the yields from rows in wide-spaced and single-stalk blocks of Acala cotton in section B, San Antonio, Tex., 1914. Wide-spaced rows are represented by double lines, single-stalk rows by heavy lines.

for the greater differences in the yields obtained from the alternate rows of section A.

Because of the effect of single-stalk rows on wide-spaced rows throughout the test, it is necessary to compare the inside rows of the 4-row blocks of section B in order to learn the differences that might be expected if the planting had been made upon a field basis. It is found by doing this that the inside rows of single-stalk blocks yielded from 15 to 60 per cent more seed cotton than the inside rows of the wide-spaced blocks. The average difference is 47.7 per cent.

The yields from the guard row that separated sections A and B proved more interesting than was anticipated. This row, which was not thinned at any time during the season, contained 594 plants and yielded more than either the nearest wide-spaced or single-stalk row. A section of this row is illustrated in Plate V, figure 1. The nonthinned row yielded 23.7 pounds of seed cotton, while the wide-spaced rows on either side yielded 11.4 and 11.7 pounds, respectively. The nearest single-stalk row, the second row distant, yielded 21.6 pounds. The nonthinned row yielded 104 per cent more than the wide-spaced rows and 9 per cent more than the single-stalk rows. The yields from this and other nonthinned rows in the test indicate that the full possibilities of securing advantage from leaving the plants closer together have not yet been obtained in the experiments with the single-stalk system. The fact that the nonthinned row was favorably situated between two wide-spaced rows should not, however, be overlooked.

QUALITY AND QUANTITY OF FIBER.

A careful examination of the fiber in the field resulted in the conclusion that there were no perceptible differences in the quality of the fiber produced on single-stalk and on wide-spaced plants. The length, strength, luster, drag, and evenness were compared and found to be the same.

That even closer spacing than that used in the single-stalk rows does not affect the quality of lint is shown by the fact that the fiber produced in the guard row between sections A and B, which was not thinned at any time during the season, was up to the standard in quality.

The abundance of the lint on the seed was determined as far as possible in the field and found to be the same in the single-stalk and in the wide-spaced rows. An actual ginning test corroborated the field test, proving the lint percentage to be about 32 in each case.

RESULTS IN TIME-OF-THINNING TEST.

The blocks of the "time-of-thinning" test in section C were all planted on April 14 and were thinned 25, 41, and 51 days after planting, respectively. Each block contained five rows, in which the plants were thinned to 6, 9, 12, 18, and 24 inches apart, respectively. It was not possible to arrange the rows in the same order in all of the blocks because of the poor stands in some of the rows, making it necessary to select the best rows for the closer spacings. On account of this irregular method of arrangement and also because the rows are so few in number, only a general statement of the results will be given.

With respect to vegetative-branch development it was found that the longer thinning was delayed the greater was the restriction in the branch development. There was a gradual increase in the number of branches as the distance between the plants increased, regardless of the time of thinning.

The yields were closely associated with the distance between the plants in the row. This is illustrated in Plate V, figure 2, which shows the first picking from rows of Acala cotton thinned at the ordinary time, the plants being left 6, 9, 12, 18, and 24 inches apart in the different rows. As the distance between the plants increased, the yields decreased.

The rows that were thinned late gave higher yields than those thinned either early or very late.

RESULTS IN DISTANCE-BETWEEN-ROW TEST.

As in other sections the rows in the "distance-between-row" test of section D were planted on April 14. This section contained four blocks, in which the rows were spaced to 3, 4, 5, and 6 feet apart, respectively. The blocks contained 8, 6, 5, and 4 rows, respectively. In all the blocks single-stalk rows alternated with wide-spaced rows. The wide-spaced rows were chopped 25 days after planting and the single-stalk rows 47 days after planting. This test was also limited, and as the results are indicative rather than conclusive only a general summary is given.

The boll census showed that as the distance between the rows increased, the percentage of 4-locked bolls decreased, this decrease being offset by a corresponding increase in the percentage of 5-locked bolls. The wide-spaced rows had a smaller percentage of 4-locked bolls and a greater percentage of 5-locked bolls than the single-stalk rows, regardless of the distance between the rows. Single-stalk rows 6 feet apart gave higher acre yields than wide-spaced rows either 3, 4, 5, or 6 feet apart.

The results of this experiment suggest the desirability of further testing the single-stalk system of culture in rows 5 or more feet apart in dry regions.

SUMMARY.

Drought and boll-weevil ravages shorten the period during which bolls are set in the region of San Antonio, and a cotton crop must be set ordinarily in about one month. In 1914 the crop was set in about 25 days. Because of the very short season of setting the crop, the single-stalk system of cotton culture promises to be especially useful.

The single-stalk and wide-spaced systems of culture were compared in alternate single rows and alternate 4-row blocks in rows 4 feet apart and again in alternating rows 3, 4, 5, and 6 feet apart. In one instance plants were thinned early, late, and very late to 6, 9, 12, 18, and 24 inches apart. The stand was satisfactory in all cases.

The spring of 1914 in the region of San Antonio was cooler than usual, and more than twice the normal amount of rain fell during

April and May. No rain fell between the first of June and early in August. These abnormal conditions caused a restriction in the development of vegetative branches. That the single-stalk system was effective in still further reducing vegetative growth is shown by the fact that even though the average number of vegetative branches produced on plants in wide-spaced rows was only 1.6, on single-stalk plants it was reduced to 0.53 branch per plant.

More flowers were produced daily on the single-stalk rows than on the adjoining wide-spaced rows. At the end of 40 days single-stalk rows alternating with wide-spaced rows had produced 84 per cent more flowers than the latter. In alternating blocks single-stalk rows had produced 78 per cent more flowers than wide-spaced rows in the adjoining block.

Single-stalk rows produced an average of 5.5 bolls per plant and wide-spaced rows 8.6 bolls per plant. The difference in the number of bolls per plant was much more than offset by the greater number of plants in the single-stalk rows, so that the single-stalk rows set from 50 to 150 per cent more bolls in the same row space.

A larger percentage of 4-locked bolls was produced in single-stalk rows and in rows close together than in wide-spaced rows where the plants were set either close together or far apart.

The bolls in the single-stalk rows were slightly smaller than those in the wide-spaced rows. Nineteen 4-locked bolls from single-stalk rows were required to equal the weight of eighteen 4-locked bolls from wide-spaced plants. The ratio of weight for 5-locked bolls is 11 to 10 for single-stalk and wide-spaced rows, respectively.

The plants in single-stalk rows were taller than those in wide-spaced rows. The single-stalk rows were spreading at the top, while the wide-spaced rows were broader near the ground.

In all cases single-stalk rows yielded more than the adjoining wide-spaced rows, regardless of the distance between the rows.

An examination of the fiber in the field showed that there was no perceptible difference in the quality or quantity of lint produced in single-stalk and in wide-spaced rows.

Plants thinned to a few inches apart in the row had fewer vegetative branches than plants spaced farther apart, the thinning having been done at the same time in each case. Late-thinned plants had fewer vegetative branches than plants thinned earlier to the same distance.

Early thinning and late thinning gave higher yields than very late thinning.

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HENRY W. HENSHAW, Chief

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FOOD HABITS OF THE THRUSHES OF THE UNITED STATES.

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CONTENTS.

INTRODUCTION.

North American thrushes (Turdidæ) constitute a small but interesting group of birds, most of which are of retiring habits but noted as songsters. They consist of the birds commonly known as thrushes, robins, bluebirds, Townsend's solitaire, and the wheatears. The red-winged thrush of Europe (*Turdus musicus*) is accidental in Greenland, and the wheatears (*Saxicola œnanthe* subspp.) are rarely found in the Western Hemisphere except in Arctic America. Within the limits of the United States are 11 species of thrushes, of which the following 6 are discussed in this bulletin: Townsend's solitaire (*Myadestes townsendi*), the wood thrush (*Hylocichla mustelina*), the veery and willow thrush (*Hylocichla fuscescens* subspp.), the gray-cheeked and Bicknell's thrushes (*Hylocichla aliciæ* subspp.), the olive-backed and russet-backed thrushes (*Hylocichla ustulata* subspp.), and the hermit thrushes (*Hylocichla guttata* subspp.). An account of the food habits of the 5 species of robins and bluebirds appeared in Department Bulletin No. 171.

As a group thrushes are plainly colored and seem to be especially adapted to thickly settled rural districts, as the shyest of them, with

Note.—This bulletin treats of the economic relations and value to agriculture of the thrushes of the United States other than robins and bluebirds. These two forms were discussed in Department Bulletin No. 171, issued February 5, 1915.

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the exception of the solitaire, do not require any greater seclusion than that afforded by an acre or two of woodland or swamp.

The thrushes are largely insectivorous, and also are fond of spiders, myriapods, sowbugs, snails, and angleworms. The vegetable portion of their diet consists mostly of berries and other small fruits. As a family thrushes can not be called clean feeders, for the food eaten often contains a considerable proportion of such matter as dead leaves, stems, and other parts of more or less decayed vegetation. It might be supposed that this was gathered from the ground with insects and other food, but investigation shows that much of it has a different origin. It was noticed that the setæ or spines of earthworms were a very common accompaniment of this decayed vegetation. Earthworms themselves are rather rarely found in stomachs, although some birds, as the robin, eat them freely. It is well known that the food of earthworms consists largely of partially decayed vegetable matter found in the soil. Hence it is probable that decayed vegetation found in the stomachs of thrushes is the food contained in the earthworms when they were swallowed. The tissues of worms are quickly digested, leaving the contents of their alimentary canals mixed with the hard indigestible setæ or spines.

Thrushes of the genus *Hylocichla* show a very pronounced taste for ants, and the average consumption of these insects by the five species is 12.65 per cent. Few birds other than woodpeckers show so strong a liking for this highly flavored food. Hymenoptera in general, including ants, bees, and wasps, are the second largest item of insect food. Lepidoptera (caterpillars) stand next as an article of thrush diet, while Orthoptera (grasshoppers), which are a favorite food with most birds, do not seem to appeal much to the thrushes.

The thrushes are pronounced ground feeders, and may often be seen picking small fruit that has fallen to the ground. The vegetable portion of their food (40.72 per cent) is largely composed of fruit, which constitutes over 34 per cent of the total food. Of this 30.88 per cent is made up of wild berries, which outweigh the domestic varieties with every species. In all, 94 species of wild fruits or berries were identified in the stomachs of these birds, although it is not always practicable to identify such material unless seeds or some other characteristic parts are present. As this is not often the case, a considerable portion of the stomach contents must be pronounced "fruit pulp" without further identification; thus probably many more species are eaten than are recorded. Moreover, in the case of some fruits, it is not possible to distinguish species by the seeds, so that many species go unrecognized except as to genus. Domestic fruits are eaten so sparingly by the thrushes here considered as to be of no economic importance.

TOWNSEND'S SOLITAIRE

(*Myadestes townsendi.*)

Townsend's solitaire, a bird of the far West, is a resident of high mountains and lonely gorges. It is partial to running streams and often builds its nest just above a rushing mountain torrent. It ranges from Alaska through the Sierras south to San Bernardino, Cal., and through the Rockies to Arizona and New Mexico, and occasionally farther east. The species is not evenly distributed over this region, but is restricted to such high mountainous portions as afford its favorite surroundings. As long as it retains these habits the bird will have little or no effect upon the products of husbandry, and its food can have only a scientific interest. The song of this species is said to be at times the finest of any of the thrush family.

As this bird is comparatively rare in settled regions only 41 stomachs are available for determining the character of its food. The most southerly and easterly one was taken in Texas, the most westerly in California, and the most northerly in Wyoming. They are distributed through all the months of the year, although April and May are represented by but one each and December by but two. Every other month has three or more. An investigation based upon such limited material can be considered only as preliminary, but will serve to show some of the more important elements of the food. This was made up of 35.90 per cent of animal matter to 64.10 of vegetable.

Animal food.—The animal food consists of insects and spiders, with a few hair worms (*Gordius*) found in one stomach. These last may have been contained in the insects eaten. Among insects, beetles constitute the second largest item (10.74 per cent), but 5.89 per cent of these were the useful predatory ground beetles (Carabidæ). This is not a good showing, but too few stomachs have been examined to allow sweeping conclusions. As evidence that this can not be taken as a fair sample of the bird's food habits it may be stated that all of these beetles were taken in January and October. The one stomach collected in January contained 95 per cent of Carabidæ—the only animal food in it—and 93 per cent of the contents of one October stomach was made up of the same material. Evidently in these cases the bird had found a colony of the beetles and filled up with them. Had they constituted the usual diet of the species they would have appeared in other months and in more stomachs, but in smaller quantities. Other families of beetles are eaten so sparingly as to be of little importance. Scarabæidæ stand the next highest, but they amount to less than 2 per cent of the food.

Lepidoptera (caterpillars) make the largest item in the food of *Myadestes*. Eaten much more regularly than beetles, they probably are a standard article of diet. They were found in the stomachs collected in every month of the year but four, and a greater number of stomachs would probably show them in every month. The one stomach taken in May contained the maximum (72 per cent). The total for the year is 12.95 per cent. Ants are eaten to the extent of 4.71 per cent, while other Hymenoptera, as bees and wasps, make up less than half of 1 per cent. Diptera (flies) are represented by a mere trace in the stomachs. Observers who have seen this bird in its native haunts testify that it takes a considerable portion of its food on the wing. In view of this fact it seems curious that the two orders of insects most active on the wing (Hymenoptera and Diptera) should be so scantily represented in the food. Hymenoptera are a standard diet with flycatchers and would seem to be the natural food of any bird that feeds upon the wing.

Hemiptera (bugs) were found to the extent of 3.51 per cent of the total food. All were contained in three stomachs taken in March, June, and July. In the July stomach four cicadas, or dog-day flies, constituted the whole contents. Grasshoppers amount to less than 1 per cent and all other insects to but a trifle. Spiders were eaten to the extent of 2.94 per cent of the food and were found in the stomachs taken in seven of the twelve months, and judging from their distribution they are eaten whenever available. A hair snake (*Gordius*) was found in one stomach. Following is a list of insects identified and the number of stomachs in which found:

COLEOPTERA.		HEMIPTERA.	
Amara erratica	1	*Platypedia putnami*	1
Aphodius sp	1		
Balaninus sp	1		

Vegetable food.—The vegetable portion of the food of *Myadestes* is 64.10 per cent of the whole, and 58.70 per cent of this, or more than half the whole food, is classified as wild fruit or berries. These were found in stomachs collected in every month. From the even distribution of this food through the year and from the quantity eaten it is evidently a favorite article of diet. Nothing was found in any of the stomachs that could be identified as cultivated fruit, with the possible exception of a mass of fruit pulp found in one. A few seeds of poison ivy and sumac, with fragments of flowers and a few weed seeds, complete the vegetable food. Following is a list of fruits, seeds, etc., identified, and the number of stomachs in which found:

Rocky Mountain cedar (*Juniperus scopulorum*)	3	Wild cherries (*Prunus* sp.)	1
Western cedar (*Juniperus monospermum*)	1	Sumac berries (*Rhus* sp.)	1
Other cedars (*Juniperus* sp.)	2	Poison ivy (*Rhus toxicodendron*)	1
Hackberries (*Celtis occidentalis*)	1	Waxwork (*Celastrus* sp.)	1
Douglas hackberries (*Celtis douglasii*)	1	Madrona berries (*Arbutus menziesii*)	5
Service berries (*Amelanchier* sp.)	1	Honeysuckle berries (*Lonicera* sp.)	1
Rose haws (*Rosa* sp.)	2	Elderberries (*Sambucus* sp.)	1
		Fruit not further identified	3

Summary.—With so small an amount of material it is not safe to draw general conclusions, but in the case of *Myadestes* one point seems clear—the bird's favorite food is small wild fruit, and as long as this is abundant the bird will probably not attack cultivated varieties; but should any portion of the region occupied by the solitaire be cleared of its wild fruit and cultivated species be introduced these would likely be preyed upon. Under such conditions this bird, now perfectly harmless, might inflict considerable damage.

WOOD THRUSH.

(*Hylocichla mustelina.*)

The wood thrush is distributed over the eastern part of the United States wherever suitable conditions are found. It is a lover of open groves and bushy pastures, and may be found along little-traveled roads and near low bushy swamps. The bird is noted for its sweet song, and many country people who are well acquainted with its notes know little or nothing of the bird itself. Its favorite time for singing is in the early evening at the close of a sultry afternoon when a shower has cooled the air. As a rule, it does not nest in gardens or orchards and is seldom seen about farm buildings. It is strictly migratory, and the greater number pass out of the United States in winter, though a few remain in the Southern States. It usually migrates north in April or early May.

For the investigation of the food habits of the wood thrush 171 stomachs were available. One of these was collected in Florida in January and another in Alabama in February, and these two will be treated separately. The remaining 169 were collected from April to October, and are fairly well distributed over that time. The food consisted of 59.59 per cent of animal matter to 40.41 per cent of vegetable. The greatest quantity of animal food was eaten in April, the month of arrival from the south, and the least in October, the month of the return migration.

Animal food.—Beetles, collectively (20.40 per cent), constitute the largest item of animal food. Of these, 2.23 per cent are the predacious ground beetles (Carabidæ), generally considered useful. The remainder belong to several more or less harmful families, of which the May-beetle family (Scarabæidæ) amount to 10.17 per cent. Snout beetles, or weevils (Rhynchophora), are eaten to the extent of 2.16 per cent only, and the wood-boring chick-beetles (Elateridæ) to 2.13 per cent.

Among the various species of these insects were noted the remains of the well-known Colorado potato beetle (*Leptinotarsa decemlineata*), in two stomachs, and *Coptocycla signifera*, also injurious to the potato, in one stomach. Remains of *Otiorhynchus ovatus*, a weevil destructive to strawberry plants, were found in two stomachs, and in one other a weevil, *Sphenophorus parvulus*, that injures the roots of grass. The well-known white grubs that attack grass roots and a host of other plants are the immature forms of many species of *Lachnosterna*, of several species of *Euphoria* and of *Allorhina nitida*. Of these, remains of *Lachnosterna* were found in 27 stomachs and of *Allorhina* and *Euphoria* in one each.

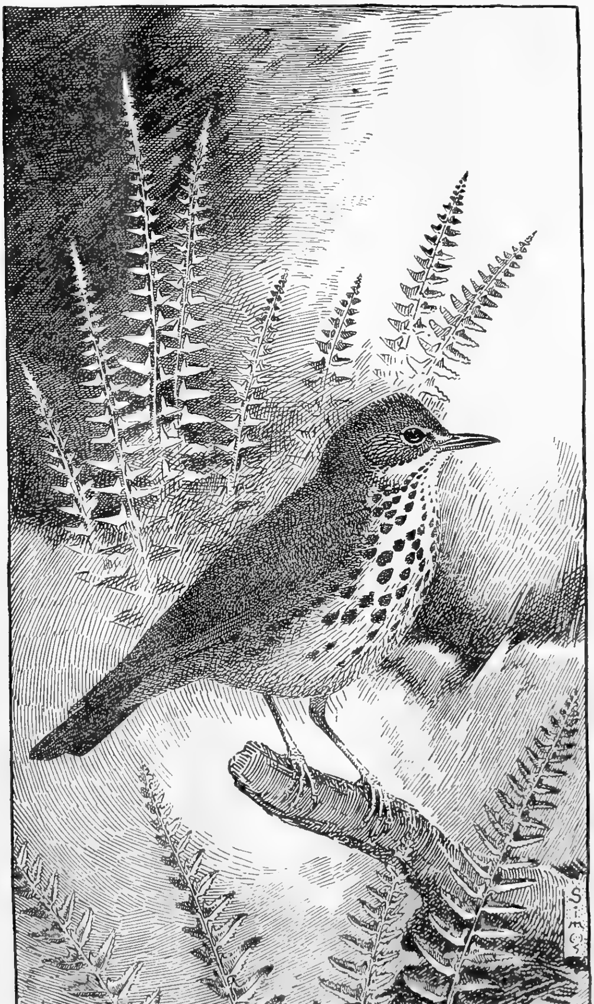

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FIG. 1.—Wood thrush (*Hylocichla mustelina*).

Lepidoptera (caterpillars) stand next to Coleoptera (beetles) in the animal diet of the wood thrush. Although eaten with a fair degree of regularity during every month of the bird's stay in the north, the most were taken in July (16.32 per cent). The average for the season is 9.42 per cent. Ants as an item of food are third in importance, though if other Hymenoptera were included the order would rank next to beetles. They seem to be a rather favorite food with all birds of the genus *Hylocichla*. With the wood thrush they begin with 18.12 per cent in April and gradually decrease through the summer and disappear in October. The total for the season is 8.89 per cent. Hymenoptera other than ants were eaten with great regularity (3.86 per cent) throughout the season, but not in large quantities. Diptera (flies) are eaten in small quantities and rather irregularly. Most of them were the long-legged crane flies (Tipulidæ), both in the adult and larval form. The total for the season is 2.70 per cent. Hemiptera (bugs) do not appear to be a favorite food, though a few were taken in all of the seven months except October. The average for the season is only 1.33 per cent. Orthoptera (grasshoppers) are eaten in small quantities until July, after which they form a fair percentage till September. The total consumption amounts to 2.28 per cent of the food. A few other insects make up a fraction of 1 per cent. Spiders and myriapods (thousand-legs) appear to be a favorite food with the wood thrush, constituting in April 20.94 per cent of the food, but gradually decreasing in quantity until September. The aggregate for the year is 8.49 per cent. A few sowbugs (isopods), snails, and earthworms (1.83 per cent) close the account of animal food.

Following is a list of the insects identified in the stomachs of the wood thrush and the number of stomachs in which each was found:

HYMENOPTERA.	
Tiphia inornata	1
COLEOPTERA.	
Harpalus herbivagus	1
Necrophorus tomentosus	1
Philonthus lomatus	1
Hister abbreviatus	1
Hister depurator	1
Hister americanus	2
Ips quadriguttatus	1
Melanotus americanus	1
Corymbites cylindriformis	1
Agrilus bilineatus	1
Telephorus carolinus	1
Onthophagus striatulus	1
Onthophagus tuberculifrons	1
Onthophagus sp	3
Atænius sp	2
Aphodius granarius	1
Aphodius sp	1
Dichelonycha testacea	1
Dichelonycha sp	1
Lachnosterna sp	27
Ligyrus sp	1
Allorhina nitida	1
Euphoria fulgida	1
Euphoria sp	2
Chrysomela pulchra	1
Leptinotarsa decemlineata	2
Odontota sp	1
Coptocycla signifera	1
Coptocycla sp	1
Anametus griseus	1
Phyxelis rigidus	1
Otiorhynchus ovatus	2
Tanymecus confertus	1
Pandeletejus hilaris	1
Barypithes pellucidus	1
Listronotus latiusculus	1
Macrops sp	1
Conotrachelus posticatus	2
Acalles carinatus	1
Balaninus sp	2
Eupsalis minuta	1
Sphenophorus parvulus	1
HEMIPTERA.	
Nezara hilaris	2
ORTHOPTERA.	
Diapheromera femorata	1
ISOPTERA.	
Termes flavipes	1

Vegetable food.—More than nine-tenths of the vegetable food of the wood thrush can be included in a single item—fruit. Cultivated fruit, or what was thought to be such, was found in stomachs taken from June to September, inclusive. It was eaten regularly and moderately, and the total for the season was 3.74 per cent of the whole food. Wild fruits or berries of 22 species were found in 72 stomachs, distributed through every month of the bird's stay at the north. Beginning with 1.18 per cent in April, the quantity gradually increases to 87.17 per cent in October, when it makes more than five-sixths of the whole food. The average for the season is 33.51 per cent. In this investigation *Rubus* seeds (blackberries or raspberries) are always reckoned as cultivated fruit, though probably most often wild. Besides fruit, a few seeds and rose haws were found, which with a little rubbish complete the vegetable food (40.41 per cent).

Following is a list of fruits, seeds, etc., identified and the number of stomachs in which found:

Yew berries (*Taxus minor*)	1
False Solomon's seal (*Smilacina racemosa*)	1
Bayberries (*Myrica carolinensis*)	1
Mulberries (*Morus* sp.)	10
Spiceberries (*Benzoin æstivale*)	5
Currants (*Ribes* sp.)	1
Mountain ash (*Pyrus americanus*)	2
Service berries (*Amelanchier canadensis*)	2
Blackberries or raspberries (*Rubus* sp.)	17
Rose haws (*Rosa* sp.)	1
Wild black cherries (*Prunus serotina*)	1
Chokecherries (*Prunus virginiana*)	7
Domestic cherries (*Prunus cerasus*)	4
Croton (*Croton* sp.)	1
American holly (*Ilex opaca*)	2
Woodbine berries (*Psedera quinquefolia*)	1
Frost grapes (*Vitis cordifolia*)	4
Wild sarsaparilla (*Aralia nudicaulis*)	1
Flowering dogwood (*Cornus florida*)	3
Rough-leaved cornel (*Cornus asperifolia*)	4
Dogwood (*Cornus* sp.)	1
Black gum (*Nyssa sylvatica*)	1
Huckleberries (*Gaylussacia* sp.)	1
Blueberries (*Vaccinium* sp.)	6
French mulberry (*Callicarpa americana*)	1
Black elderberries (*Sambucus canadensis*)	1
Other elderberries (*Sambucus* sp.)	3
Fruit pulp not further identified	12

Of the two stomachs not included in the foregoing discussion, the one taken in Florida in January contained 93 per cent of wild fruit and 7 per cent of weevils, wasps, and spiders; the one collected in Alabama in February was entirely filled with animal food, of which 88 per cent was caterpillars, 5 per cent May beetles, 6 per cent bugs, and 1 per cent spiders.

Summary.—The animal food of the wood thrush includes remarkably few useful insects and contains some very harmful ones, as the Colorado potato beetle and many of the Scarabæidæ, the larval forms of which are the well-known white grubs which are a pest to agriculture in preying upon roots of plants. The vegetable portion of the food contains a small quantity of cultivated fruit, but observation shows that the thrush is in the habit of picking up fallen fruit instead of taking it fresh from the tree. The eating of wild fruit has no economic interest except that it serves to distribute the seeds of many shrubs and trees. There is no occasion to discriminate against this bird in any way. It should be rigidly protected.

VEERY AND WILLOW THRUSH.

(*Hylocichla fuscescens fuscescens* and *Hylocichla fuscescens salicicola.*)

The veery is distributed over the eastern portion of the United States during migration and breeds in the Northern States as far south as Pennsylvania, and in New England and Canada. In winter it disappears almost entirely from the country, only a few remaining in Florida and perhaps in other Southern States. Its western representative is the willow thrush. Like other thrushes, birds of this species are shy and retiring in disposition, keeping for the most part in the shade of woods or bushy swamps, or building nests in a damp ravine with a brook gurgling past. They have been known, however, to visit orchards and sometimes gardens which are not kept too trim. It is thus evident that the food has little direct economic interest, as this bird does not come in contact with the farmer's crops.

For investigating the food of the species 176 stomachs were available. They were collected during the seven months from April to October, and represent 18 States, the District of Columbia, and Canada. The food separates into 57.27 per cent of animal matter and 42.73 per cent of vegetable. The former consists mostly of remains of insects, and the latter of fruit.

Animal food.—Predacious ground beetles (Carabidæ) amount to 0.82 per cent. They are evidently not a preferred food. Beetles in general comprise 14.67 per cent of the food, but no family or other group appears to be distinguished except the Carabidæ, which are conspicuous by their absence. Weevils, or snout beetles, amount to 2.49 per cent, and one stomach contained a specimen of the notorious plum curculio (*Conotrachelus nenuphar*). A number of other harmful beetles were noted, but none are so well known as the plum destroyer. Ants make up 10.35 per cent and are eaten with great regularity. Hymenoptera other than ants amount to only 3.26 per cent, but are eaten regularly throughout the season. Hemiptera (bugs) were eaten to a small extent (1.30 per cent) in the first four months, but they are not seen after July. Exactly the same may be said of Diptera, which total only 0.85 per cent.

Lepidoptera (caterpillars) are, next to Hymenoptera, the favorite insect food. They were eaten in goodly quantities in every month except October. The average for the season is 11.91 per cent. Grasshoppers appear to some extent in every month except April, the greatest consumption taking place in October (24 per cent), but as only small numbers are eaten in the earlier months the aggregate for the year is only 4.91 per cent. A few other insects of various orders amount to 0.98 per cent. Spiders (6.34 per cent) are eaten regularly and constantly through the season, except that none were taken in October. A few sowbugs, snails, etc. (2.70 per cent), complete the quota of animal food. Following is a list of insects identified and the number of stomachs in which found:

HYMENOPTERA.	
Tiphia inornata	1
COLEOPTERA.	
Elaphrus ruscarius	1
Anisodactylus harrisi	1
Anisodactylus sp	1
Pterostichus lucublandus	1
Hydrobius fuscipes	1
Ips fasciata	1
Byrrhus murinus	1
Dolopius lateralis	2
Limonius æger	1
Corymbites cylindriformis	1
Corymbites spinosus	1
Cormybites tarsalis	1
Corymbites hieroglyphicus	1
Podabrus flavicollis	1
Telephorus bilineatus	2
Telephorus sp	1
Onthophagus sp	2
Atænius cognatus	1
Aphodius sp	3
Dichelonycha sp	2
Serica sericea	1
Lachnosterna hirticula	1
Lachnosterna sp	13
Chrysomela pulchra	3
Chlamys plicata	1
Typophorus canellus	1
Graphops simplex	1
Graphops sp	1
Calligrapha philadelphica	1
Œdionychis quercata	1
Microrhopala vittata	1
Hormorus undulatus	1
Phyxelis rigidus	1
Otiorhynchus ovatus	1
Neoptochus adspersus	1
Cercopeus chrysorrhœus	2
Barypithes pellucidus	2
Sitones sp	2
Phytonomus nigrirostris	2
Conotrachelus nenuphar	1
Conotrachelus posticatus	1
Tyloderma sp	1
Monarthrum mali	1
Xyloteres politus	1
DIPTERA.	
Bibio sp	1

Vegetable food.—The vegetable portion of the food of the species is made up of fruit, with a few seeds and a little miscellaneous matter more or less accidental. Fruit collectively amounts to 35.30 per cent, of which 12.14 per cent was thought to be of cultivated varieties and so recorded, while the remainder, 23.16 per cent, was quite certainly of wild species. This percentage of cultivated fruit is more than three times the record of the wood thrush, while the wild fruit eaten is correspondingly less, as the sum total of the fruit consumed is very nearly the same with both birds. From this percentage of domestic fruit one might infer that the veery was, or might be, a serious menace to fruit growing, but no such complaints have been heard, and it is probable that the species is not numerous enough to damage cultivated crops. A close inspection, however, of the fruit eating of the veery removes all doubts. The cultivated fruit, so called, was in every case either strawberries or *Rubus* fruits, i. e., blackberries or raspberries, and as both of these grow wild and in abundance wherever the veery spends its summer, it is probable that all of the fruit eaten was taken from wild plants, though 12.14 per cent has been conventionally recorded as cultivated.

Besides fruit, the veery eats a few seeds of grasses and weeds and a few of sumac, but none of the poisonous species were found in the stomachs. These seeds (7.25 per cent of the food) were eaten so irregularly as to suggest that they are merely a makeshift taken for want of something better. Rubbish (0.18 per cent), consisting of decayed wood, bits of leaves, plant stems, etc., completes the vegetable food.

Following is a list of the items of vegetable food and the number of stomachs in which found:

Yew berries (*Taxus minor*)	1	Other sumac (*Rhus* sp.)	1
Pigeon grass seed (*Chætochloa* sp.)	1	American holly (*Ilex opaca*)	1
Rush grass seed (*Sporobolus minor*)	1	Woodbine berries (*Psedera quinquefolia*)	1
False Solomon's seal (*Smilacina* sp.)	1	White cornel (*Cornus candidissima*)	2
Greenbrier berries (*Smilax* sp.)	2	Alternate-leaved cornel (*Cornus alternifolia*)	3
Hackberries (*Celtis occidentalis*)	1	Rough-leaved cornel (*Cornus asperifolia*)	1
Poke berries (*Phytolacca decandra*)	3	Dogwood berries (*Cornus* sp.)	2
Spice berries (*Benzoin æstivale*)	2	Sour gum berries (*Nyssa sylvatica*)	1
Service berries (*Amelanchier canadensis*)	3	Huckleberries (*Gaylussacia* sp.)	1
June berries (*Amelanchier* sp.)	9	Blueberries (*Vaccinium* sp.)	4
Mountain ash (*Pyrus americana*)	1	Snowberries (*Symphoricarpos racemosus*)	2
Crab apples (*Pyrus* sp.)	1	Black elderberries (*Sambucus canadensis*)	2
Strawberries (*Fragaria* sp.)	3	Red elderberries (*Sambucus pubens*)	4
Blackberries or raspberries (*Rubus* sp.)	8	Other elderberries (*Sambucus* sp.)	3
Wild black cherries (*Prunus serotina*)	1	Fruit pulp not further identified	4
Bird cherries (*Prunus pennsylvanica*)	1		
Chokecherries (*Prunus virginiana*)	1		
Staghorn sumac (*Rhus hirta*)	2		
Dwarf sumac (*Rhus copallina*)	1		
Three-leaved sumac (*Rhus trilobata*)	1		

Summary.—It is hardly necessary to make a summary of the food of this bird in order to bring out its good points, for it seems to have no others. The animal food includes less than 1 per cent of useful beetles, and the remainder is either harmful or neutral. In the matter of vegetable food there seems to be no chance for criticism, as nature evidently supplies all it needs. The bird has never been harmed, but has been held in high esteem for sentimental reasons; let it also be valued and protected for its economic worth.

GRAY-CHEEKED AND BICKNELL'S THRUSHES.

(*Hylocichla aliciæ aliciæ* and *Hylocichla aliciæ bicknelli.*)

The gray-cheeked thrush (*H. a. aliciæ*) is found in migration over all the Eastern States, but breeds farther north, beyond our limits. Bicknell's thrush (*H. a. bicknelli*), a closely related form, while having somewhat the same general range, breeds farther south and nests in the mountains of northern New York and New England. Both subspecies have the same general habits as other forms of the genus so far as haunts and choice of residence are concerned, but their far-northern range excludes them from coming into contact with cultivated crops. The species does not seem to be very abundant anywhere, and consequently only a few stomachs have been received for examination. In all they number but 111 and are very irregularly distributed in time. None were taken in August and only one in July and two in June. From so scanty and unevenly distributed material it is impossible to draw final conclusions, but we can get some idea as to the nature of the bird's food and its economic importance.

The first analysis of the food gives 74.86 per cent of animal matter to 25.14 per cent of vegetable. This is the most animal food found in the stomachs of any bird of the genus *Hylocichla* and the largest but two of any of the thrushes.

Animal food.—Beetles collectively amount to about one-third of all the food (33.32 per cent). Of these, 2.83 per cent are the useful Carabidæ. The rest belong to harmful families, such as the Scarabæidæ, Elateridæ, and the weevils, or snout beetles. Ants amount to 16.34 per cent and are eaten very regularly—the most in the early part of the season. Hymenoptera other than ants, as wasps and bees, were eaten to the extent of 5.60 per cent, and with the ants make 21.94 per cent, placing this food next in rank to beetles. As in the case of ants, most of the bees and wasps were eaten in the first three months of the season. No honey bees were found. Lepidoptera (caterpillars) were third in order of abundance (8.81 per cent). No special pest was discovered, but all caterpillars may be considered as harmful. A few grasshoppers were found in the stomachs taken in April and May, and more in those collected in September and October. They do not appear to be a favorite food and amount to only 1.72 per cent. Other insects, as flies, bugs, and a few others, collectively amount to 2.89 per cent. Among these, it is of interest to note in one stomach the remains of the famous seventeen-year locust (*Tibicen septemdecem*), rather large game for so small a bird. Spiders are freely eaten by the gray-cheeked thrush in spring, and sparingly in fall. For the season they constitute 5.77 per cent of the food. A few other animals, as crawfish, sowbugs, and angleworms (0.41 per cent), complete the animal food.

Following is a list of the insects identified and the number of stomachs in which found:

HYMENOPTERA.	
Lophyrus, sp	1
Aphænogaster tennesseense	1
COLEOPTERA.	
Cychrus andrewsi	2
Cychrus sp	2
Dyschirius hispidus	1
Hister sedecimstriatus	1
Phelister vernus	1
Epuræa rufa	3
Stelidota 8-maculata	1
Byrrhus murinus	1
Eucinetus morio	1
Monocrepidius vespertinus	1
Agriotes limosus	1
Corymbites signaticollis	1
Podabrus flavicollis	1
Telephorus bilineatus	1
Onthophagus sp	1
Atænius strigatus	1
Atænius ovatulus	1
Atænius sp	3

Aphodius ruricola	1	*Sitones* sp	1
Aphodius inquinatus	3	*Hylobius pales*	1
Aphodius sp	1	*Desmoris constrictus*	1
Serica sp	1	*Bagous sellatus*	1
Lachnosterna sp	10	*Anthonomus sycophanta*	1
Anomala sp	1	*Conotrachelus posticatus*	2
Leptura sphæricollis	1	*Acalles clavatus*	1
Leptura mutabilis	1	*Acalles* sp	1
Chrysomela pulchra	4	*Cryptorhynchus ferratus*	1
Blapstinus metallicus	1	*Sphenophorus melanocephalus*	1
Helops micans	1		
Hormorus undulatus	1	HEMIPTERA.	
Otiorhynchus ovatus	1		
Cercopeus chrysorrhœus	2	*Tibicen septendecem*	1
Pandeletejus hilaris	1	*Nezara hilaris*	1

Vegetable food.—A few *Rubus* seeds were recorded as cultivated fruit, but they were found in only two stomachs and probably were wild, as the gray-cheeked thrush does not live where it is likely to come in contact with cultivated blackberries or raspberries. In any case they amount to only 0.15 per cent. Wild fruits of 18 different species (23.98 per cent) make up nearly one-fourth of the whole food—in fact, the vegetable food, other than wild fruit, is insignificant. Wild berries supplement the regular food, which consists of insects and spiders.

The following list shows the fruits and seeds identified and the number of stomachs in which found:

False spikenard (*Smilacina racemosa*)	1	Flowering dogwood (*Cornus florida*)	5
Greenbrier berries (*Smilax* sp.)	2	Rough-leaved dogwood (*Cornus asperifolia*)	2
Bayberries (*Myrica carolinensis*)	1	White cornel (*Cornus candidissima*)	1
Poke berries (*Phytolacca decandra*)	2	Dogwood (*Cornus* sp.)	1
Crab apples (*Pyrus* sp.)	1	Sour gum (*Nyssa sylvatica*)	2
Wild black cherries (*Prunus serotina*)	5	Black nightshade (*Solanum nigrum*)	1
Blackberries or raspberries (*Rubus* sp.)	2	Dockmackie (*Viburnum acerifolium*)	1
Sumac berries (*Rhus* sp.)	1	Arrowwood (*Viburnum* sp.)	1
Black-alder berries (*Ilex verticillata*)	1	Elderberries (*Sambucus canadensis*)	3
Wild grapes (*Vitis* sp.)	5	Fruit not further identified	6
Wild sarsaparilla (*Aralia* sp.)	1		

Summary.—In the food of the gray-cheeked thrush the only useful element is a small percentage (2.83) of useful beetles. The remainder of the animal food is composed of either harmful or neutral elements. The vegetable food, drawn entirely from nature's great storehouse, contains no product of human industry, either of grain or fruit. Whatever the sentimental reasons for protecting this bird, the economic ones are equally valid.

OLIVE-BACKED AND RUSSET-BACKED THRUSHES.

(*Hylocichla ustulata swainsoni* and *Hylocichla ustulata ustulata.*)

The olive-backed thrush and its relative, the russet-backed, occupy the whole of the United States at some time during the year. The olive-back breeds north of our northern border, except in the higher mountains, and the russet-back on the Pacific coast nests as far south as southern California. The habits of birds of this species resemble those of others of the genus in living in swamps and woodlands rather than in gardens and orchards. The russet-back on the Pacific coast, however, seems to have become quite domestic, and wherever a stream runs through or past an orchard or garden, or the orchard is near thick chaparral, this bird is sure to be found taking its toll of the fruit and rearing its young in the thicket beside the stream. During the cherry season it takes a liberal share of the fruit, but its young, then in the nest, are fed almost entirely on insects. The eastern subspecies, on the contrary, does not come in contact with domestic fruit or any other product of husbandry. A great number of the subspecies nest far north of the region of fruit raising.

For this investigation 403 stomachs of the olive-backed thrush were available, collected in 25 States, the District of Columbia, and Canada. Florida, Louisiana, and Texas represent the most southern collections and New Brunswick, Ontario, and Northwest Territory the most northern. In California 157 stomachs were obtained; which, with those taken in Oregon and Washington, fairly represent the Pacific coast region. The whole collection was fairly well distributed over the nine months from March to November. The food consisted of 63.52 per cent of animal matter to 36.48 per cent of vegetable.

Animal food.—Beetles of all kinds amount to 16.29 per cent. Of these 3.14 per cent are the useful Carabidæ. The others belong to harmful or neutral families. Weevils or snout beetles (Rhynchophora) amount to 5.29 per cent, a high percentage for such insects. One Colorado potato beetle (*Leptinotarsa decemlineata*) was found in a stomach taken on Long Island. Hymenoptera collectively aggregate 21.50 per cent. Of these, 15.20 per cent are ants—a favorite food of *Hylocichla*. The remainder (6.30 per cent) were wild bees and wasps. No honeybees were found. Caterpillars, which rank next in importance in the food of the olive-back, form a good percentage of the food of every month represented and aggregate 10.30 per cent for the season.

Grasshoppers are not an important element in the food of thrushes, as they chiefly inhabit open areas, while *Hylocichla* prefers thick damp cover, where grasshoppers are not found. An inspection of the record shows that most of the orthopterous food taken by the olive-back consists of crickets, whose habits are widely different from those of grasshoppers, and which are found under stones, old logs, or dead herbage. The greatest quantity is taken in August and September. The average for the season is 2.42 per cent.

Diptera (flies) reach the rather surprisingly large figure of 6.23 per cent. These insects are usually not eaten to any great extent except by flycatchers and swallows, which take their food upon the wing. The flies eaten by the olive-back are mostly crane flies (Tipulidæ) or March flies (*Bibio*), both in the adult and larval state. Crane flies are slow of wing and frequent shady places. The larvæ of both groups are developed in moist ground, and often in colonies of several hundred. With these habits it is not surprising that they fall an easy prey to the thrushes.

Hemiptera (bugs), a small but rather constant element of the food, were found in the stomachs collected every month, and in July reach 11.11 per cent. They were of the families of stinkbugs (Pentatomidæ), shield bugs (Scutelleridæ), tree hoppers (Membracidæ), leaf hoppers (Jassidæ), and cicadas. Some scales were found in one stomach. The total for the season is 3.76 per cent. A few insects not included in any of the foregoing categories make up 0.48 per cent of the food. Spiders, with a few millipeds, amount to 2.22 per cent, the lowest figure for this item of any bird of the genus *Hylocichla.* Snails, sowbugs, angleworms, etc. (0.32 per cent), complete the animal food.

Following is a list of insects identified and the number of stomachs in which found:

HYMENOPTERA.

Camponotus pennsylvanicus	1
Tiphia inornata	1

COLEOPTERA.

Cychrus nitidicollis	1
Cychrus stenostomus	1
Notiophilus æneus	1
Pterostichus sayi	1
Pterotichus lustrans	1
Amara interstitialis	1
Triæna longula	1
Agonoderus pallipes	1
Silpha ramosa	1
Staphylinus cinnamopterus	1
Tachyporus californicus	1
Chilocorus orbus	1
Scymnus sp	1
Hister americanus	1
Ips quadriguttatus	4
Cytilus sericeus	1
Agriotes stabilis	1
Podabrus flavicollis	2
Podabrus modestus	2
Silis lutea	1
Telephorus carolinus	1
Telephorus bilineatus	5
Telephorus divisus	2
Onthophagus hecate	1
Onthophagus striatulus	1
Onthophagus tuberculifrons	2
Onthophagus sp	4
Atænius abditus	1
Aphodius hamatus	1
Aphodius fimetarius	6
Aphodius inquinatus	7
Aphodius sp	6
Geotrupes sp	1
Dichelonycha elongata	2
Lachnosterna hirticula	1
Lachnosterna sp	12
Anomala undulata	1
Anomala sp	1
Euphoria fulgida	1
Donacia emarginata	1
Hæmonia nigricornis	1
Syneta pallida	1
Leptinotarsa decemlineata	1
Gastroidea sp	1
Galerucella decora	1
Diabrotica soror	1
Diabrotica sp	1
Gonioctena pallida	1
Luperodes bivittatus	1
Opatrinus notus	1
Blapstinus metallicus	1
Blapstinus mœstus	1
Blapstinus sp	1
Otiorhynchus ovatus	1
Thinoxenus sp	1
Cercopeus chrysorrhœus	1
Barypithes pellucidus	1
Sitones flavescens	1
Sitones sp	1
Phytonomus punctatus	2
Pachylobius picivorus	1
Conotrachelus posticatus	1
Micromastus elegans	1
Acalles clavatus	1
Cryptorhynchus bisignatus	1
Rhinoncus pyrrhopus	1

Balaninus sp	3
Sphenophorus parvulus	1
Sphenophorus sp	1
Scolytus muticus	1
LEPIDOPTERA.	
Edema albifrons	1
TRICHOPTERA.	
Phryganea californica	1
HEMIPTERA.	
Myodocha serripes	1
Sinea diadema	1

This list of insects contains a considerable number of injurious species and some that at various times and places have become decided pests. Such are the Colorado potato beetle (*Leptinotarsa decemlineata*), the spotted squash beetle (*Diabrotica soror*), the cloverleaf weevil (*Phytonomus punctatus*), and the various species of *Lachnosterna*, the parent of the destructive white grubs. Many others are plant feeders and may increase to such an extent as to inflict great damage upon agriculture.

Vegetable food.—The vegetable food of the olive-backed thrush consists of small fruit. The bird has a weak bill and can not break through the tough skin of the larger kinds. In the cherry orchards of California the writer many times observed the western subspecies of this bird, the russet-back, on the ground pecking at cherries that had been bitten open and dropped by linnets and grosbeaks. Blackberries and raspberries have a very delicate skin and are successfully managed by weak-billed birds, so that all the records of domestic fruit eaten by the eastern form relate to these berries, and it is probable that in most cases the fruit was not cultivated. The total of cultivated fruit for the season is 12.63 per cent of the whole food, but if we consider the eastern subspecies alone this item would practically disappear. Wild fruit (19.73 per cent) is eaten regularly and in a goodly quantity in every month after April. Weed seeds and a few miscellaneous items of vegetable food (4.04 per cent) close the account.

Following is a list of vegetable foods so far as identified and the number of stomachs in which found:

White cedar seeds (*Thuja occidentalis*)	1
Red cedar berries (*Juniperus communis*)	2
False Solomon's seal (*Smilacina trifolia*)	3
Greenbrier (*Smilax tamnifolia*)	1
Cat brier (*Smilax* sp.)	1
Hackberry (*Celtis occidentalis*)	3
Mulberry (*Morus* sp.)	2
Fig (*Ficus* sp.)	3
Pale persicaria (*Polygonum lapathifolium*)	1
Poke berries (*Phytolacca decandra*)	9
Mountain ash (*Pyrus americana*)	1
Service berries (*Amelanchier* sp.)	1
Blackberries or raspberries (*Rubus* sp.)	67
Rose haws (*Rosa* sp.)	1
Wild black cherries (*Prunus serotina*)	15
Bird cherries (*Prunus pennsylvanica*)	2
Domestic cherries (*Prunus cerasus*)	29
Domestic plum (*Prunus domestica*)	2
Apricot (*Prunus armeniaca*)	3
Filaree (*Erodium* sp.)	1
Poison oak (*Rhus diversiloba*)	4
Staghorn sumac (*Rhus hirta*)	2
Dwarf sumac (*Rhus copallina*)	3
Other sumac (*Rhus* sp.)	4
Pepper tree (*Schinus molle*)	1
American holly (*Ilex opaca*)	1
Black alder (*Ilex verticillata*)	1
Coffee berries (*Rhamnus californicus*)	3
Woodbine (*Psedera quinquefolia*)	10
Frost grape (*Vitis cordifolia*)	6
Spikenard (*Aralia racemosa*)	2
Flowering dogwood (*Cornus florida*)	7
Kinnikinnik (*Cornus amomum*)	2

Red osier (*Cornus stolonifera*)	1	Snowberries (*Symphoricarpos racemosus*)	2
Panicled cornel (*Cornus paniculata*)	3	Dockmackie (*Viburnum accrifolium*)	1
Dogwood unidentified (*Cornus* sp.)	6	Arrowwood (*Viburnum* sp.)	1
Huckleberries (*Gaylussacia* sp.)	1	Black elderberries (*Sambucus canadensis*)	6
Three-flowered nightshade (*Solanum triflorum*)	1	Red elderberries (*Sambucus pubens*)	5
Nightshade unidentified (*Solanum* sp.)	8	Blue elderberries (*Sambucus glauca*)	15
Black twinberries (*Lonicera involucrata*)	2	Tarweed (*Madia* sp.)	1
Honeysuckle berries (*Lonicera* sp.)	2	Fruit pulp not further identified	17

Food of young of russet-backed thrush.—Before concluding the discussion of this species it will be of interest to note the results obtained from an investigation of stomachs of 25 nestlings of the russet-back taken in June and July when the birds were from two to eleven days old. These were from eight broods, ranging from three to five nestlings to the brood. The percentage of animal food of the young (92.60 per cent) is considerably higher than that of the parent birds.

The distribution of the animal food is as follows: Caterpillars were found in every stomach but seven and aggregated nearly 27 per cent; beetles, including the useful Carabidæ (7.7 per cent), are irregularly distributed to the extent of 22 per cent; other more or less harmful species included five families of (Hemiptera) bugs, 13.8 per cent, viz, stinkbugs, leaf hoppers, tree hoppers, shield bugs, and cicadas; ants and a few other Hymenoptera amount to 12 per cent, and spiders the same. These latter were mostly harvestmen or daddy longlegs (Phalangidæ). The remainder (6 per cent) included a few miscellaneous insects. Only three stomachs contained remains of grasshoppers. Carabid beetles were eaten by the young birds to the extent of 7.7 per cent, which is more than three times the amount eaten by the adults, a remarkable fact when is considered that these insects are very hard shelled, thus seemingly unsuited for young birds.

The vegetable food consisted of fruit (6.8 per cent), mainly blackberries or raspberries, found in 11 stomachs, and twinberries in 1, and two or three other items, including a seed of filaree and some rubbish. From the irregular variety of food in the different stomachs, it would seem that the parents make little selection, but fill the gaping mouths of their young with the nearest obtainable supply.

In addition to the examination of stomach contents of nestlings two nests were carefully and regularly watched, and from these it was determined that the parent birds fed each nestling 48 times in 14 hours of daylight. This means 144 feedings as a day's work for the parents for a brood of three nestlings, and that each stomach was filled to its full capacity several times daily, an illustration that the digestion and assimilation of birds, especially the young, are constant and very rapid. Experiments in raising young birds have proved that they thrive best when fed small quantities at short intervals rather than greater quantities at longer periods. Aside from the insects consumed by the parents, a brood of three young birds will thus each require the destruction of at least 144 insects in a day and probably a very much greater number.

Summary.—In a résumé of the food of the olive-backed and russet-backed thrushes one is impressed with the fact that they come in contact with the products of industry but rarely. The olive-back's food habits infringe upon the dominion of man but little. The bird lives among men, but not with them. The western form, the russet-back, comes more into relations with the cultivated products because it visits orchards and partakes freely of the fruit. Even then the damage is slight, as much of the fruit eaten is that fallen to the ground. Moreover, while the adult bird is feeding upon fruit a nestful of young are being reared upon insects which must be largely taken from the orchard, thus not only squaring the account but probably overbalancing it in favor of the farmer.

HERMIT THRUSHES.

(*Hylocichla guttata* subspp.)

The hermit thrush of the subspecies *H. g. pallasi* inhabits the Eastern States in winter as far north as Massachusetts and breeds from the mountains of Maryland and Pennsylvania and from northern Michigan and central Minnesota northward to Alaska. Several other subspecies occupy the Pacific coast region in suitable localities—that is, in the higher and more wooded sections, as this bird, like all of the genus *Hylocichla*, does not live in treeless or arid regions. In the East the bird is a late fall migrant and may often be seen sitting silent and alone on a branch in the forest in late October or even in November, when the great army of migrants have passed on to the South. While a beautiful songster, the species is so quiet and unobtrusive that by sight it is entirely unknown to many.

Inquiry into the food habits of this bird covered 551 stomachs, collected in 29 States, the District of Columbia, and Canada, and representing every month of the year, though all the stomachs taken in winter were collected in the Southern States the District of Columbia, and California. In the primary analysis the food was found to consist of 64.51 per cent of animal matter to 35.49 per cent of vegetable. The former is mostly composed of insects with some spiders, while the latter is largely fruit, chiefly wild species.

Animal food.—Beetles constitute 15.13 per cent of the food. Of these 2.98 per cent are of the useful family, Carabidæ. The remainder are mostly harmful. Scarabæidæ, the larvæ of which are the white grubs that destroy the roots of so many plants, were eaten to the extent of 3.44 per cent. Snout beetles, among the most harmful of insects, were taken to the extent of 3.13 per cent. Among these was the notorious plum curculio (*Conotrachelus nenuphar*) found in two stomachs taken in the District of Columbia in April of different years. Two other species of the same genus also were found, as well as the clover weevil (*Epicærus imbricatus*). The Colorado potato beetle (*Leptinotarsa decemlineata*) and the striped squash beetle (*Diabrotica vittata*), with a number of other species of less notoriety, were found in several stomachs. Thus, in spite of the bird's retiring habits, it comes in contact with some of the pests of cultivation.

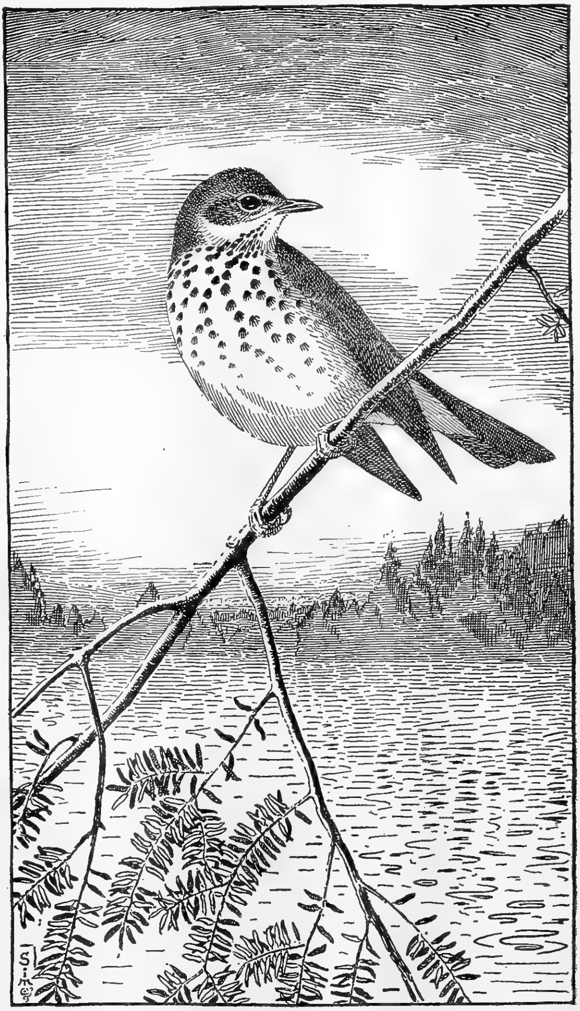

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FIG. 2.—Hermit thrush (*Hylocichla guttata*).

The ants destroyed—12.46 per cent of the food—keep up the reputation of thrushes as ant eaters. They were taken constantly every month, with the greatest number from May to September; a falling off in July is partly accounted for by the fact that more fruit is taken in that month. Other Hymenoptera (bees and wasps) were eaten to the extent of 5.41 per cent, a suprising amount for a bird that feeds so largely upon the ground, as these insects are usually of fleet wing and live in sunshine and open air.

Caterpillars, eaten in every month and mostly in goodly quantities, appear to be a favorite food of the hermit thrush. December is the month of least consumption (2.75 per cent), while the most were eaten in June (17.08 per cent). The average for the year is 9.54 per cent. Hemiptera (bugs) seem to be eaten whenever found, as they appear in the food of every month, but rather irregularly and not in large quantities. The greatest consumption was in June (9.17 per cent), but July, September, and December show the least (less than 1 per cent). The total for the year is 3.63 per cent. Of the six families represented, the Pentatomidæ, or stink bugs, predominate. These highly flavored insects are eaten by most insectivorous birds often, but usually in small quantities.

Diptera (flies) comprise 3.02 per cent of the food of the hermit thrush. The record shows, however, that nearly all of them are either crane flies (Tipulidæ) and their eggs and larvæ, or March flies (*Bibio*) and their larvæ. Over 150 of the latter were found in one stomach. Both of these families of flies lay their eggs in the ground, which accounts for their consumption by ground-feeding birds. Orthoptera (grasshoppers and crickets) are eaten by the hermit thrush to the extent of 6.32 per cent of its food. While this figure is not remarkable, it is the highest for any of the genus. These birds are fond of dark moist nooks among trees and bushes and do not feed extensively in those dry sunshiny places so much frequented by grasshoppers. A close inspection of the food record shows that the Orthoptera eaten by the thrushes are mostly crickets, which live in shadier and moister places than those where grasshoppers abound. A few miscellaneous insects (0.27 per cent) close the insect account. Spiders and myriapods (7.47 per cent) seem to constitute a very acceptable article of diet, as they amount to a considerable percentage in nearly every month, and in May rise to 20.79 per cent. A few miscellaneous animals, as sowbugs, snails, and angleworms, make up the balance of the animal food (1.26 per cent).

Following is a list of insects so far as identified and the number of stomachs in which found:

HYMENOPTERA.	
Tiphia inornata	2
COLEOPTERA.	
Elaphrus sp	1
Notiophilus semistriatus	1
Scarites subterraneus	1
Dyschirius pumilis	1
Pterostichus patruelis	1
Pterostichus sp	1
Amara sp	1
Chlænius pennsylvanicus	2
Stenolophus sp	1
Anisodactylus agilis	1
Tropisternus limbalis	2
Hydrocharis obtusatus	1
Sphæridium lecontei	1
Ptomaphagus consobrinus	1
Anisotoma valida	1
Megilla maculata	1
Anatis 15-maculata	1
Psyllobora tædata	1
Brachycantha ursina	1
Endomychus biguttatus	1
Cryptophagus sp	1
Hister marginicollis	1
Hister americanus	1
Saprinus fimbriatus	1
Carpophilus hemipterus	1

Perthalycra murrayi	1
Ips quadriguttatus	3
Cytilus sericeus	2
Cytilus sp	1
Byrrhus kirbyi	1
Byrrhus cyclophorus	1
Cryptohypnus bicolor	2
Drasterius dorsalis	1
Dolopius lateralis	1
Melanotus sp	2
Podabrus tomentosus	1
Canthon sp	1
Onthophagus tuberculifrons	1
Onthophagus sp	3
Ægialia lacustris	1
Rhyssemus scaber	1
Atænius abditus	1
Atænius cognatus	1
Atænius sp	1
Aphodius fimetarius	11
Aphodius granarius	1
Aphodius rugifrons	1
Aphodius inquinatus	9
Aphodius pardalis	1
Aphodius prodromus	4
Aphodius crassiusculus	1
Aphodius sp	11
Geotrupes semipunctata	1
Dichelonycha sp	1
Lachnosterna sp	17
Chrysomela pulchra	3
Lema nigrovittata	1
Chlamys plicata	1
Myochrous denticollis	2
Xanthonia 10-notata	1
Calligrapha scalaris	1
Leptinotarsa decemlineata	1
Phædon viridis	1
Diabrotica vittata	1
Odontota rubra	1
Odontota sp	1
Haltica torquata	1
Crepidodera helxines	1
Syneta ferruginea	1
Systena elongata	1
Chætocnema pulicaria	1
Psylliodes punctulata	1
Chelymorpha cribraria	1
Opatrinus notus	1
Opatrinus aciculatus	1
Blapstinus metallicus	1
Blapstinus rufipes	1
Salpingus virescens	1
Anthicus pubescens	1
Notoxus monodon	1
Notoxus denudatum	1
Notoxus sp	1
Attelabus rhois	1
Rhigopsis effracta	1
Cercopeus chrysorrhœus	4
Pandeletejus hilaris	1
Barypithes pellucidus	1
Sitones hispidulus	4
Sitones flavescens	1
Trichalophus alternatus	1
Apion sp	1
Listronotus latiusculus	1
Listronotus inæqualipennis	1
Listronotus sp	1
Macrops sp	2
Smicronyx corniculatus	1
Trachodes ptinoides	1
Conotrachelus nenuphar	2
Conotrachelus posticatus	5
Conotrachelus erinaceus	1
Rhinoncus pyrrhopus	1
Onychobaris insidiosus	1
Balaninus nasicus	1
Balaninus sp	1
Sphenophorus parvulus	1
Sphenophorus sp	1
Dendroctonus terebrans	1

HEMIPTERA.

Podops cinctipes	1
Nezara hilaris	6
Arhaphe cicindeloides	1
Corimelæna denudata	1
Myodocha serripes	2

ORTHOPTERA.

Amblycorypha rotundifolia	1
Œcanthus niveus	1

Vegetable food.—The vegetable diet of the hermit thrush consists largely of fruit, as with most birds of this group. As might be expected of a bird of such retiring habits, but little of the fruit eaten can be classed as cultivated. In September 5.45 per cent was so considered, but in most months the quantity was small, and in March, April, and May was completely wanting. The total for the year as found in 17 stomachs is 1.20 per cent. One stomach contained strawberries, one grapes, one figs, one currants, two apples, and the rest *Rubus* fruit, i. e., blackberries or raspberries. These last as well as the strawberries were probably wild. Of the wild fruit (26.19 per cent) 46 species were identified with a reasonable degree of certainty in 243 stomachs. A few seeds, ground-up vegetable matter not further identified, and rubbish make up the rest of the vegetable food (8.10 per cent). Among the seeds were some of the various species of poisonous *Rhus*. These were found in 18 stomachs, mostly from California. The dissemination of these seeds is unfortunate from the standpoint of husbandry, but many birds engage in it, as the waxy coating of the seeds is nutritious, especially in winter, when fruit and insects are not easily obtainable.

Following is a list of the components of the vegetable food so far as identified, and the number of stomachs in which found:

Cedar berries (*Juniperus virginiana*)	2
False Solomon's seal (*Smilacina racemosa*)	4
False spikenard (*Smilacina* sp.)	1
Greenbrier (*Smilax walteri*)	2
Cat brier (*Smilax bona-nox*)	2
Laurel-leaved greenbrier (*Smilax laurifolia*)	1
Other greenbriers (*Smilax* sp.)	11
Wax myrtle (*Myrica cerifera*)	1
Bayberries (*Myrica carolinensis*)	7
Chinquapin (*Castanea pumila*)	1
Western hackberries (*Celtis occidentalis*)	5
Other hackberries (*Celtis* sp.)	3
Figs (*Ficus* sp.)	1
Mulberries (*Morus* sp.)	1
Mistletoe berries (*Phoradendron villosum*)	2
Poke berries (*Phytolacca decandra*)	16
Miner's lettuce (*Montia perfoliata*)	1
Sassafras berries (*Sassafras varifolium*)	2
Spice berries (*Benzoin æstivale*)	1
Currants (*Ribes* sp.)	3
Sweet gum (*Liquidambar styraciflua*)	2
Chokeberries (*Pyrus arbutifolia*)	1
Service berries (*Amelanchier canadensis*)	9
Hawthorn (*Cratægus* sp.)	1
Strawberries (*Fragaria* sp.)	1
Blackberries or raspberries (*Rubus* sp.)	5
Rose haws (*Rosa* sp.)	1
Wild black cherries (*Prunus serotina*)	3
Three-seeded mercury (*Acalypha virginica*)	1
Staghorn sumach (*Rhus typhina*)	5
Smooth sumach (*Rhus glabra*)	5
Dwarf sumach (*Rhus copallina*)	7
Poison ivy (*Rhus radicans*)	3
Poison oak (*Rhus diversiloba*)	15
Laurel-leaved sumach (*Rhus laurina*)	2
Other sumachs (*Rhus* sp.)	12
Pepper berries (*Schinus molle*)	15
American holly (*Ilex opaca*)	9
Black alder (*Ilex verticillata*)	12
Ink berries (*Ilex glabra*)	9
Other hollies (*Ilex* sp.)	7
Strawberry bush (*Euonymus americanus*)	1
Roxbury waxwork (*Celastrus scandens*)	1
Supple-jack (*Berchemia volubilis*)	2
Coffee berries (*Rhamnus californicus*)	1
Woodbine (*Psedera quinquefolia*)	10
Frost grapes (*Vitis cordifolia*)	2
Wild grapes (*Vitis* sp.)	1
Wild sarsaparilla (*Aralia nudicaulis*)	1
Flowering dogwood (*Cornus florida*)	32
Rough-leaved dogwood (*Cornus asperifolia*)	2
Black gum (*Nyssa sylvatica*)	2
Checkerberry (*Gaultheria procumbens*)	1
Huckleberries (*Gaylussacia* sp.)	1
Blueberries (*Vaccinium* sp.)	12
Black nightshade (*Solanum nigrum*)	4
Bittersweet (*Solanum* sp.)	4
Goose grass (*Galium aparine*)	1
Honeysuckle (*Lonicera* sp.)	2
Indian currant (*Symphoricarpos orbiculatus*)	1
Downy arrowwood (*Viburnum pubescens*)	1
Nanny berries (*Viburnum lentago*)	2
Black elderberries (*Sambucus canadensis*)	4
Red elderberries (*Sambucus pubens*)	3
Fruit not further identified	60

In looking over this list one is impressed with the fact that the taste of human beings for fruit differs markedly from that of birds. For example, *Rhus* seeds are hard and have little pulp to render them palatable or nutritious. They are usually passed through the alimentary canal of birds or regurgitated unharmed, and the slight outer coating alone is digested. In the case of the poisonous species, this outer coating is a white wax or tallow which appears to be very nutritious, for these species are eaten much more extensively than the nonpoisonous ones. The seed itself is rarely broken in the stomach to get any nutriment it may contain. But in spite of these facts *Rhus* seeds were found in 49 stomachs, while fruits of huckleberries and blueberries, which are delicious to the human taste, were found in only 13 stomachs; and blackberries and raspberries, highly esteemed by man, were found in only 5 stomachs. Next to *Rhus* the fruit most eaten was the dogwood berry, found in 34 stomachs, yet from a human estimate these berries are distasteful and contain such large seeds that they afford but very little actual food.

Summary.—The hermit thrush, as it name indicates, is of solitary habits and neither seeks human companionship nor molests cultivated products. It destroys nothing indirectly helpful to man, as beneficial insects, but aids in the destruction of the myriad hosts of insect life which at all times threaten vegetation. While it is not easy to point out any especially useful function of the hermit thrush, it fills its place in the economy of nature, from which it should not be removed.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 281

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C. ▼ August 12, 1915

CORRELATING AGRICULTURE WITH THE PUBLIC SCHOOL SUBJECTS IN THE NORTHERN STATES.

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CONTENTS.

INTRODUCTION.

Home projects [1] as a part of the regular instruction in elementary agriculture promise to afford the teacher a most potent means of making the subject sufficiently concrete and practical. Too often the teaching begins and ends with the assignment and recitation of lessons from the pages of a textbook. By projecting the work of the school into the home in the vital way in which home projects do, it enlists the interest of parents and becomes the means of their education in this subject, thus affecting quickly the work on the farms of the community.

The purpose of this bulletin is to suggest some ways and means by which the public-school teacher may utilize home projects in correlating agriculture and farm problems with the regular school work.

[1] The term "home project," applied to instruction in elementary and secondary agriculture, includes each of the following requisites: (1) There must be a plan for work at home covering a season more or less extended, (2) it must be a part of the instruction in agriculture of the school, (3) there must be a problem more or less new to the pupil, (4) the parents and pupil should agree with the teacher upon the plan, (5) some competent person must supervise the home work, (6) detailed records of time, method, cost, and income must be honestly kept, and (7) a written report based on the record must be submitted to the teacher. This report may be in the form of a booklet.

NOTE.—This bulletin is prepared especially for the use of rural school teachers in the Northern States.

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THE PLAN.

The term "correlation" is here used to mean nothing more nor less than leading pupils to see the relation between home life and school life, to point out the utility value of arithmetic, geography, and physiology, and to supplement reading, history, language, and spelling. Thus through home projects and correlations there will be lent to rural school agriculture a realness and concreteness that can be obtained in no other way.

It will be observed that the material is arranged according to a monthly sequence plan. Ten months' work is provided for, but in case the school term is not so long, as is generally true in rural schools, the work out of season may be dropped.

As suggested by the title of this publication, the correlation scheme is intended to be adapted to the northern, central, and western sections of the United States. Covering as it does a large territory, the work must of necessity be largely suggestive. The details, such as the statement of problems, working of subjects in language exercises, etc., should be left to the teacher. Gathering local data as a basis for the work should be entrusted in a large measure to the club members of the school.

HOW THE TEACHER MAY ORGANIZE A CLUB.

Home projects may be carried on without an organization, but if the teacher desires to form a club he should, as soon as possible after the school opens in the fall, write to the county superintendent and State leader in charge of boys' and girls' clubs at the State agricultural college for all printed matter available pertaining to club projects. When the teacher has studied the literature and has become familiar with the plans, projects, rules, etc., of clubs, a meeting for organization should be called and should include as many boys and girls of the school district as can be brought together. It would be well to invite the patrons of the school to this meeting and have the extension representative (county agent) for the county give a talk on the agricultural club requirements and work. If possible, have the county superintendent of education and the State leader in charge of club work at this meeting and ask their aid in this organization work. Near the close of the meeting, which should not be too long, a simple form of constitution and set of by-laws may be adopted, and the regular officers of the club elected at this time may include a supervisor, president, vice president, secretary, treasurer, and program committee.

As a suggestion to teachers who have not thus far taken up club work, the following general form of organization has been found satisfactory:

SUGGESTED CONSTITUTION AND BY-LAWS.[1]

CONSTITUTION.

ARTICLE I. *Name of club.*—This organization shall be known as .... School Boys' and Girls' Agricultural Club.

ART. II. *Objects of club.*—The objects of the club shall be to make farm life more attractive and farming more profitable.

ART. III. *Membership.*—Boys and girls from 10 to 18 years of age, inclusive, shall be eligible.

ART. IV. *Officers.*—The officers of this club shall be a supervisor, president, vice president, secretary, and treasurer.

ART. V. *Duties of members.*—Prescribed in the rules for club work, such as follow instructions, attend club meetings, make exhibits at the school and county fair, and keep a report of expenses, income, observations, and work.

ART. VI. *Duties of officers.*—The president shall preside at all meetings; the secretary shall keep the minutes and records of all such meetings; the treasurer must care for all funds collected and shall pay out the same only upon the written order of the president, and the vice president may act as president in the absence or disability of that officer. The teacher shall be the local leader, having the general supervision of all local club work and power of exercising authority in proper management of the club.

SEC. 1. An advisory committee shall arrange for all public contests and exhibits, the procuring and awarding of prizes, and the reporting of statistics and other information to the State organizer.

BY-LAWS.

1. The members of the club shall agree to read all reference literature bearing upon the home project. This may include literature dealing with the growing of corn, potatoes, tomatoes, chickens, pigs, etc.
2. A written plan of the work of each boy and girl must be prepared for the teacher. They must do all the work connected with the particular contest or project entered upon.
3. The amount of yield by weight and measurement of land and other results of the spring and summer work must be certified to by the contestant and attested by at least two disinterested competent witnesses preferably members of the local school board who are not relatives.
4. Every member of the club must make an exhibit at the annual school fair.
5. In estimating profits the recommendations of the State agent in charge of boys' and girls' club work will be observed. Rent of land $...., work of club members .... cents per hour, work of horses .... cents per hour each, manure $.... per two-horse wagon load.
6. No club member should be allowed to receive more than .... prizes.

[1] The teacher should write the State agent in charge of club work at the State agricultural college for suggestions concerning the organization and conducting of a boys' and girls' agricultural club, or, in the absence of such State agent, he may write directly to the U. S. Department of Agriculture, Washington, D. C., for such assistance. The office for extension work of the U. S. Department of Agriculture in the Northern and Western States maintains a section with a leader and assistants who give their entire time to the organization and supervision of boys' and girls' club work in cooperation with the extension divisions of the agricultural colleges in practically all of the States. The State leader in club work at the agricultural college is usually, therefore, the joint employee of the U. S. Department of Agriculture and the State agricultural college and represents both institutions alike in club work. In organizing a club, therefore, through the assistance of this State leader the boys and girls are brought into and become a part of the State organization as well as of the national organization for club work and receive systematic recognition and assistance from both the State and the Nation.

7. The committee of judges for the annual school fair shall be selected by the local leader.

8. Exhibits winning prizes at the school fair should be sent to the annual county contest and even to the State contest.

9. The percentage score for a, b, c, and d is subject to change from time to time in the different States. The recommendations of the State club leaders for the Northern and Western States for 1914–15 were as follows:

	Per cent.
(a) Greatest yield per acre	30
(b) Best exhibit	20
(c) Essay and report	20
(d) Best showing of profit on investment	30
Total	100

PRIZES.

The matter of prizes is of considerable importance. While the various contests of the club members have for their primary object the assistance of the teacher and the public schools to find an easy approach, educationally, to all the interests of rural and village life and to form a connecting link between parent and teacher, farm and school, it is found that prizes can be used to advantage. An attempt should be made to offer a large number of prizes. Many small prizes are better than a few large ones. Among the prizes suggested as suitable awards in club contests for first place the following may be mentioned:

(1) Free trips and expenses paid to district and State fairs, educational institutions, summer Chautauquas, etc.

(2) Top buggy, saddle, gold watch, automobile, etc.

(3) Clear title to one or more acres of land (to encourage land ownership).

(4) Farm implements, tools, equipment, etc.

(5) Thoroughbred pigs, cattle, horses, mules, pen of chickens.

(6) Club emblems, banners, and pennants.

(7) Manual-training workbench, set of tools, camera, trunk, leather handbag, writing desk, etc.

(8) Poultry equipment, such as incubators, watering and feeding troughs, brooders, fencing, and gates.

(9) Free tuition to short courses in agricultural and mechanical colleges and regular courses in colleges.

(10) Canvas tent, camp outfit, canoe, hunting equipment, baseball suit, and suit of clothes.

(11) Dictionary, encyclopedia, set of agricultural books, special club library, series of books of standard literature.

(12) Subscriptions to farm journals, magazines, and special periodicals for boys.

School credit should be given to every member of the club who carries to completion some one club project. Every boy and girl should be taught the real meaning and value of a prize and that a realization of work well done is the true reward of effort.

HOW TO KEEP UP THE CLUB INTEREST.

The success of the rural school club depends largely upon the cooperation of the rural school teacher, county superintendent of education, extension representative (county agent), and the club leader of the State college of agriculture. Shortly after the club is organized in any rural school the teacher should submit the names of the members to the county superintendent of education, who will assist in furnishing the club with literature directing them in the work. The teacher will find it advantageous to have the extension representative (county agent) make talks before the school, as well as visit the contestants' home projects as he makes his rounds from time to time. The teacher should visit the homes of all club members and, together with the boys and girls and any other members of their families, go to the prize acres, etc., and have the owners tell the methods of preparing the soil, fertilizing, and cultivating the crop. The results of such a trip will present much material for discussion at club meetings and regular class instruction in agriculture. For every school club there should be a local committee of three men and three women who will encourage the children, interest influential members of the community in the club, and inspect from time to time the work of the club.

SCHOOL-EXHIBIT DAY.

In order to bring to a close the contest work of the boys and girls, one day of the school year should be set apart for the display of the club projects and of their other efforts. The small exhibit in the local school is of most value, and often it is possible for two or more schools to combine in having their school exhibit.

To make the school exhibit a success, not only the children but the parents must be enlisted. The social element in it is very important. Every parent must be so interested that he will feel he must be present. Plan for an entire day given to the special occasion. If there is one in the vicinity who can give anything valuable to agriculture, secure him as a speaker. If this is done, have two programs, one in the forenoon for the speaker and one in the afternoon when the children shall take the prominent place.

Have the children's program plan to show the results of the club-project work and other home efforts. Let it include the best compositions written on the more interesting phases of the work. The history of corn, the importance of corn in America, the development of breakfast foods, my experience in growing corn, my success with poultry, games that I like on the farm, why farmers should spray, value of birds to the farmer, and number of days of work needed for one man and a team to raise and harvest an acre of corn are suggested as additional subjects.

The history and work of the farmers' institute should be reported by one of the older pupils; another should give an account of what the agricultural college is doing for the State.

If sufficient interest has been aroused, contests in judging corn, breadmaking, rope tying, and seed-corn stringing might be held. For judging the exhibits prepared by the pupils secure some one who has studied corn judging, poultry judging, etc. Be sure to make this a feature of the day, making the announcement of the results a part of the program.

Music should not be omitted from the program. Some patriotic music should be included, as should the State song.

Plan to have dinner at the school and use every device possible to utilize products grown by the children. If the number of people is not too large, a splendid lesson in art would be the making of place cards and decorating them with some corn design. If these are not made, souvenirs of the day should be made by the pupils, carrying out some particular club-project idea. This is one real way to teach decorative art.

For a language lesson prepare written invitations to the patrons of the school. Perhaps the form side of notes of invitation will be more vividly taught then. Be sure to include the local editor in the list of invitations. Have a report of School Exhibit Day written by some of the pupils for the local papers.

The decoration of the schoolroom should not be neglected. Blackboard drawings, booklets, corn products, and other work of the pupils should be utilized. Use some fine specimens of corn in completing the decorations. The room should be decorated so as to give joy and impress the thought that the man who tills the soil is engaged in an exalted work.

SEPTEMBER.

Practical and field exercises.—Select seed corn in the field and have a schoolroom demonstration of methods of curing. (See Correlation Supplements II and III on pp. 26, 27.) Cooperate in the canning of surplus tomatoes. Arrange that each pupil shall report on the local or county fair visited, and it is well for the teacher to attend with the pupils. Take a field trip to collect seeds, weeds, insects, and other illustrative material. (See Farmers' Buls. 586 and 606.) Observe the condition of fields; recognize and destroy weeds. Visit the project fields of pupils when possible on these excursions. (See score card on corn in Supplement XIV.) Prepare to hold a school exhibit or fair. (Refer to Supplement I.) Have pupils exhibit some of their produce at the county fair. (Fig. 1.)

Language lessons.—Have all pupils use notebooks when doing field work. Utilize the club-work material for both oral and written descriptions. Have the summer experiences written up fully for each club project, not as a language lesson first, but for its content, and then revise. Have the pupils write and mail requests for bulletins needed, also for periodicals and catalogues. Have written such parts of the report on project work as are due at this time. Do a part of the work on the booklet to correspond with the field progress. (See Supplement on Booklets, No. VIII.)

Reading and spelling.—Use those selections in the supplementary reading books which are rural in their bearing and which are seasonal. Utilize also the best selections available in other books. The teacher may well read some of these for the entire school. Among those possible for September will be found Maize—Fosdick; The Legend of

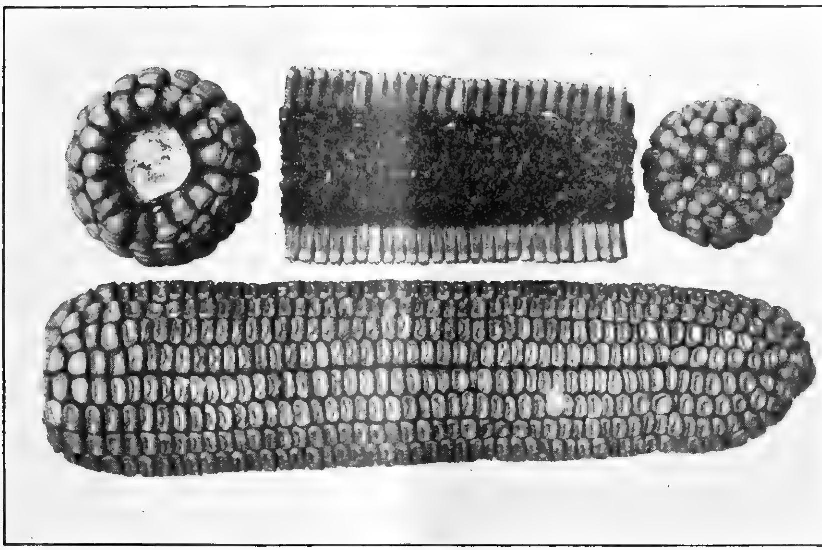

FIG. 1.—Desirable ear of corn. Selected by the Division of Corn Investigations, Bureau of Plant Industry.

Maize (in Hiawatha)—Longfellow; Eyes and No Eyes—Kingsley; Happy the Man—Pope; To a Waterfowl—Bryant; Evening at the Farm—Trowbridge; Bobwhite—Cooper. Memorize the Country Boy's Creed, by E. O. Grover.

Of a more strictly agricultural nature select those periodicals and bulletins which deal with the local conditions and the club activities of the pupils. Farmers' Bulletins which may be needed include Nos. 229, The Production of Good Seed Corn; 415, Seed Corn; 537, How to Grow an Acre of Corn; 578, The Making and Feeding of Silage; 617, School Lessons on Corn.

Add to the regular spelling lists all the new words which appear in the agricultural reading and especially those which are misspelled in the written exercises. Make sure that the terms are all pronounced correctly. Mispronunciation makes misspelling almost inevitable, and the pupils should use the proper term in each case.

Arithmetic.—The summer records of the projects ought to furnish the figures for problems of all sorts. Areas of fields, stand of corn, averages of yields, rate per acre, cost per acre, increase of yield over seed, gain over cost in amount and rate, interest rate on investment, rate of yield in relation to average for State, cost per egg of producing eggs, tomato incomes and net profit, probable per cent profit from the canned tomatoes, are some of the possible problems. The capacity of silos is a problem suited to some districts. Have the problem relate to the class work of the month or to review work in arithmetic as well as to agriculture. The correlation should work both ways or it is unfair. Remember other phases of community and home life deserve correlation. (See problems in Supplement XIII.)

Geography.—Have pupils make several copies of maps of the district and the township. Get original maps from county or township surveys or make from observations of district. On one locate the winners of prizes on different exhibits at the fairs. This will help in finding suitable material on field trips. Have pupils obtain data as to earliest severe frosts for the section and compare with other sections. On the State map locate the chief crops of various sections, also make note of particularly successful boys' and girls' clubs. Note what crops are yielding well in the different States and discuss climatic factors. (See the latest issue of The Monthly Crop Report.[1]) Apply the same method to international crops, commerce, etc., making use not only of census and other statistics but also the current information gained from magazines and farm papers. Make comment on the crop per acre at home and abroad and seek explanations.

History.—Consider the agricultural, industrial, and social facts connected with the period in history which a class is studying. Look up in various history texts the story of corn in the United States, also have pupils inquire into the farm history of your section. (See Bowman and Crosley's "Corn," Ch. I, and Montgomery's "The Corn Crops," Chs. I and II.) Trace the history of the potato in reference books and readers. Do not destroy the plan for history lessons but adapt topics to this plan. Where local histories are not printed, both tradition and scrap files of old newspapers will be helpful.

The suggestions under both history and geography are intended for the reading and inquiry by the pupils, to be followed by classroom discussion. These topics may be divided among the members of the class. Many school-history texts have separate chapters on agricul-

[1] The Monthly Crop Report is issued at monthly intervals by the United States Department of Agriculture and gives surveys of agricultural conditions in the country and other timely information which should help any rural-school teacher.

tural, industrial, and social development, and others take up these matters as a part of each epoch. Nearly every modern geography devotes much space to soils, crops, animals, the food supply, and farming as an industry. The public library usually has many helpful reference books on travel, invention, industries, as well as histories and geographies. The supplementary geographical readers and texts in history, physical geography, etc., loaned by the nearby high school will give ample reference texts. Sample copies of textbooks are usually found at the school. Personal inquiry will discover other sources of information.

Drawing.—Sketching, design, and color work may include corn subjects, weeds, fruit, and insects. Working drawings of any apparatus used in school or at home in connection with the month's lesson may be needed.

Physiology.—Food values of crops raised locally is a timely topic. See Farmers' Bul. 121, legumes; 142, general; 295, potatoes; 298, corn; 359 and 521, on canning; 375, care in home; 565, corn meal. Plant food and animal food as related to current physiology lessons should be considered. (See Brewer's Rural Hygiene, especially on local problems of fall sanitation.)

Manual training.—Make corn-drying racks, exhibit shelves and window boxes. Can tomatoes and other vegetables and fruit. Braid husk mats and baskets. Take up tender plants into pots and boxes.

OCTOBER.

Practical exercises and field trips.—Visit a contest area, measure the plat, weigh and judge the crop. Keep data for future problems. Visit flocks of high-grade poultry, especially flocks with good records for laying. Gather soils and store away in boxes or pails for future lessons on soils and for germination plats or shallow boxes in early spring. Help club members close up their projects ready for a report. Examine modern harvesting machinery while on trips. Have members store garden produce, take up tender bulbs and roots, destroy weeds and rubbish which may harbor insects or disease. Select laying flock of poultry and begin fattening for market the fowls which are not desired for laying. Club members who now plan to raise crops next year will do well to plow land this month. (Fig. 2.)

Hold the school fair this month if it was not held in September. (See Supplement I.) Much of the practical work of this month will be done by the pupils at home. Teachers should consult Farmers' Bul. 562, The Organization of Boys' and Girls' Poultry Clubs.

Language lessons.—Write out with care the reports on the club contests or project work just completed. Complete the booklet for corn, potatoes, tomatoes, and other projects. Make out new applications for club projects soon to begin. Write a description of the

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school fair for the local newspapers. Conversations in which pupils tell without interruption about some process, trip, or other experience should alternate with written exercises.

Have members of the class write formal invitations to adults requesting them to attend the school fair. Send requests for bulletins, score cards, and other material needed soon.

Reading and spelling.—Read inspirational and seasonal supplementary selections, as: The Farmers Gold—Edward Everett; Black Beauty—Sewall; The Corn Song—Whittier; The Apple—Burroughs; The Horse Fair—Baldwin; Hiawatha's Brothers—Longfellow.

Readings in practical agriculture may be found in Farmers' Buls. 51, Standard Varieties of Chickens; 287, Poultry Management; 313, Harvesting and Storing Corn; 574, Poultry House Construction.

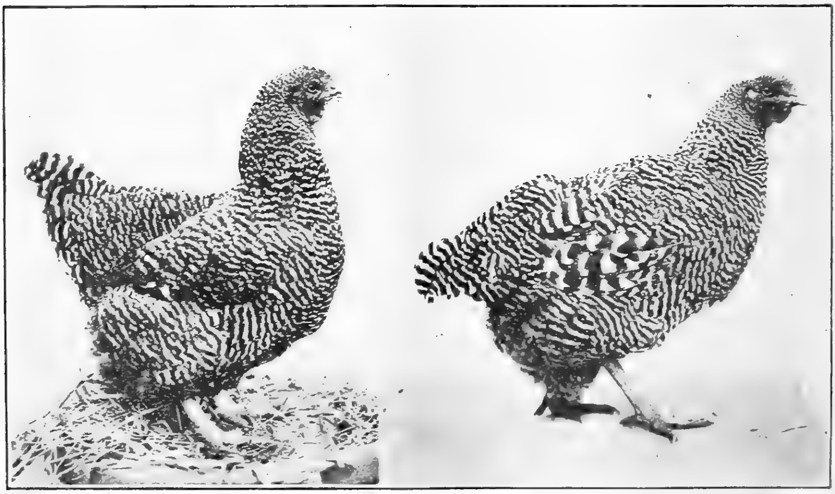

FIG. 2.—Evidences of strong and weak constitutions. Selected by Animal Husbandry Division, Bureau of Animal Industry.

Also use State bulletins and periodicals on suitable topics. Drill on words misspelled in written exercises and on new words in reading.

Arithmetic.—Make out with accuracy and neatness statements of cost and income to accompany the report on the club work. Rule columns with care and make figures plain. Compute and order bill of lumber needed for new poultry house or for remodeling, for nests or other equipment. From the figures obtained from various crops assign problems adapted to the advancement of the pupils.

Geography.—Complete a local survey of the crops and the poultry flocks of the district. Record this both on maps and on tabular charts. Have pupils look up the extent of the trade in farm produce for the State, at what points sold eventually. Find also the origin of grain and other farm produce imported from without the State.

Refer to such texts as Hunt's "Cereals in America." Have pupils make an outline map of the county and locate thereon the chief crops either by sketches or by grains, etc., glued on the map. This map will be useful in teaching younger pupils. Have a large map of the district made to be duplicated for future surveys. (See Supplement VII.)

History.—Have pupils inquire into the history of grain and fruit development in this country, especially the crops now grown in club work. Note the effect of the crops and the methods of raising them on the history of this country and the great national issues. As examples, notice cotton and tobacco in the South, grain and meat in Central States, dairying and diversified farming in New England. Trace the effect of the growth of cities on the type of agriculture in different sections, especially in supplying milk, garden truck, etc. Show how the free grant of rich lands led to careless farming because it was supposed their fertility was inexhaustible. Trace the growth of the work of the National Government and the State Government in encouraging good farming and in controlling pests and diseases. It is not to be expected that one class will develop all these topics. Select those adapted to the section and to the available reference books. Review the history of the development of harvesting machinery in the United States.

Drawing.—Make cover design for booklets. (See Supplement VIII). Make other drawings or sketches needed to complete the booklets. Use fruit, grain, and vegetables for studies in sketching, color work, and designing. Have working drawings made for new poultry house and equipment, for improved shipping and storage apparatus. Make specifications and bill of lumber for each from these drawings in arithmetic class work.

Physiology.—Take up poultry and eggs as human food. See Farmers' Buls. 128, Eggs and Their Uses as Food, and 182, Poultry as Food. Consider the feeding value and digestibility for farm animals of the crops harvested and stored from the club acre. Apply the lessons used in human physiology concerning foods and digestion. See Farmers' Buls. 22, The Feeding of Farm Animals, and 142, The Nutritive Value of Food.

Manual training.—Construct a model poultry house on a small scale. Have as many pupils as possible plan to construct poultry houses for their club flocks. Make full-sized nests and feed boxes. (See Farmers' Bul. 638.) Have the girls learn to cook and serve vegetables and fruits, also to can them and to preserve them in other ways. (See Farmers' Buls. 359 and 607.) Have them prepare and serve a variety of dishes from some of the produce of the projects and show these dishes at the exhibit. Have the mechanical work on the booklet done with care.

NOVEMBER.

Practical and field exercises.—Visit storage plants for farm produce if there are any in the section. Visit farms where the class may inspect pure-bred poultry, cows and other animals. Observe also the best methods of housing. Visit a club member's poultry house. If any orchard work is done in the district this month have reports made on this work. Pruning and scraping must be done before spraying with lime-sulphur for San José scale. (See Farmers' Buls. 181 and 492.) This may be done at any time after the trees become dormant except during freezing weather. Have apple-club members inspect for the scale, and if present it should be treated at once. Apple packing for market may be in order in some sections. Have poultry houses cleaned, repaired, and sprayed this month. Rubbish must be destroyed and vines and shrubs protected from the cold. Certain trees and shrubs may be set out now. Cuttings made during pruning of grape vines and many shrubs may be preserved in sand until spring. (See Farmers' Buls. 157 and 471.) The teachers should advise club members to do these things. Complete the collection of soils, seeds, etc., for winter use.

Language lessons.—Have reports on field trips written with care and when they are on the topic of the projects, incorporate them in the booklets. Likewise, include descriptions of structures or operations observed or used. Have oral discussions along the lines suggested in the practical exercises, trying to obtain from the pupils clear descriptions in good English.

Send letters to obtain bulletins, catalogues, tools, etc. Have the class edit a school newspaper (not printed) dealing with the affairs of the school and the club work of the district. Have this read in school and send articles of merit to the local press. Thanksgiving suggests many seasonal topics and is emphatically a rural festival.

Reading and spelling.—Include in the supplementary reading selections like Walden Pond—Thoreau; November Woods—H. H. Jackson; Farming—Emerson's Essays; The Twenty-third Psalm; Descriptions from Audubon's Writings; November—Alice Carey. Look up the story of Johnny Apple-seed in Hillis' "The Quest of John Chapman."

Continue reading in bulletins suggested for October and add Farmers' Buls. 154, The Home Fruit Garden; 491, The Small Apple Orchard; 492, Enemies of the Apple; 528, Hints to Poultry Raisers; 562, Boys' and Girls' Poultry Clubs. Also use State publications from all sources and farm papers on related topics.

Keep a list of words posted which shall include agricultural terms used in the reading texts, also words which have been misspelled or mispronounced. Have spelling exercises, both written and oral, on these lists and prepare for a public contest in connection with some neighborhood event.

Arithmetic.—Problems in corn shrinkage, marketing corn and the relative merits of feeding and marketing corn may be made from figures given in bulletins and textbooks. Select also figures concerning cost of harvesting and marketing apples, potatoes, and other crops. Compute net profits on club acres. Compute rations and cost of each for poultry and any other animals which are in home projects. Consult text and bulletins including Farmers' Bul. 22. Continue computations of material and cost of constructing poultry houses and equipment. Compute cost of feeding club flocks, egg production per hen and cost per egg or per dozen eggs. Use current market prices where eggs are used at home. Compute rate of interest on investment. (See also textbooks on Farm Arithmetic.)

Geography.—Look up climatic factors of different crops; limits in latitude, altitude, etc., for different plants. Find where the tender plants grow native, also the northern limits of the hardy plants. Find in bulletins and books on insects the origin of the orchard pests of the section. On maps and tabular charts indicate the results of the survey of the poultry of the district. Keep club members' records separately. Make a graphic representation to show the relation in numbers of pure-bred fowls to scrubs by lines with lengths in correct proportions. Put on map the roads used for market, social, and civic purposes and indicate parts needing repair.

History.—Have pupils find out where the different varieties of poultry originated and trace their introduction. Numerous poultry books give this information. Look up stories of fowls in history, as The Geese that Saved Rome. Inquire into the introduction of fruits into the section and how they have been improved. In like manner trace the history of methods of marketing the local produce. What effect have the transportation facilities had on the development of the county and State? Many texts in geography and history give this. Find how different European countries have affected American agriculture by furnishing live stock, plants, methods, and labor. Trace the history of Thanksgiving celebrations.

Drawing.—Make Thanksgiving sketches and designs. Sketch typical poultry. Make a series of colored drawings of varieties of apples. Make working drawings of any equipment needed this month. Have members of Good Roads Club make sectional drawings of good and poor roads in the district. See Farmers' Buls. 338, 505, and 597. Have pupils make a series of sketches of historical modes of transportation for the section, such as ox cart, prairie schooner, flatboat, not omitting the modern.

Physiology.—The topic of breathing leads to ventilation and exercise. Correlate the idea of human needs with the plan for making poultry pens light, well-ventilated and with ample room for exercise. The same idea must be applied to stables for dairy cows. How guard against vermin in the flock? Show how the food demand changes as winter comes. Suggest succulent winter foods for poultry and dairy.

Develop the topic of apples and other fruit for human food. Consult Farmers' Bul. 293, Use of Fruit as Food. Compare eggs and milk with other animal foods for cost and food value. Demonstrate the variety in supply of fresh foods on the farm. (See Farmers' Bul. 635.)

DECEMBER.

Practical and field exercises.—Plan to have pupils visit successful dairy farms to inspect typical animals and learn of points. Investigate also the management, the feed practice, and marketing.

Begin practice in milk testing at school if possible. Begin practice in corn judging. Examine soils in school collection and distinguish by appearance and feeling sand, clay, gravel, and humus.

Make a record of winter birds, when and where seen, what food and other habits. (See Farmers' Buls. 54, 456, 497, 506, 609, 621, and 630.) Strive to observe accurately. Use Birds in Their Relation to Man, by Weed and Dearborn, or similar books.

Language lessons.—Have report of dairy inspection carefully written. Require descriptions of an ideal ear of corn or of the best cow on the home farm. Write with care the plan for selecting a suitable ration for either the hens or the dairy cow. Write the directions for testing milk with Babcock tester. Make out with care reports or records on work done or observations made. Keep these for reference. Careful figures, plain writing, correct spelling, and clear statements are necessary on all club reports and often win the contest.

Reading and spelling.—Select supplementary readings giving an appreciation of the freedom, security, and happiness in the country in winter, such as Snow Bound—Whittier; Our Rural Divinity—Burroughs; The Winter herd scene in "Shovelhorns"—Hawkes; Wood-craft—Boy Scout's Manual; and Stories of Luther Burbank's work. Memorize The Boys That Rule the World and other poems.

Along the lines of suggested practical exercises read from available bulletins. Consult poultry bulletins previously mentioned, also Farmers' Buls. 413, Care of Milk and Its Use in the Home; 490, Bacteria in Milk; 530, Important Poultry Diseases; 602, Production of Clean Milk. If there is not published in the State a bulletin on the Babcock test one may be procured from another State or from manufacturers of testing machines.

Pupils should be encouraged to use the scientific terms in many cases, in which event they should learn to spell them. Use common terms when accurate, however.

Arithmetic.—Milk records, computing rations, butter-fat computations, poultry cost and income problems will furnish much of the practice needed. While judging corn, determine what increase per acre would result if one more average kernel per row would develop on each ear. From some of the records of insects and weed seeds eaten by the winter birds make up problems as to the possible saving to the farmer. Use also crop statistics in census report or the Yearbook of the Department of Agriculture, usually to be found in township or private libraries. Have pupils count the number of average ears in a bushel of corn raised in the district. Shell and weigh again. Have problems computed on this basis. Weigh 100 or 1,000 kernels and estimate number per bushel. Borrow scales or weigh at home.

Geography.—Locate on the township map the industries in the township and county which may be related to farming, as the gristmill, the sawmill, grain elevator, tobacco-sorting shops, broom shops, tannery, creameries, and cheese factories. Trace also the local and more distant markets for eggs, butter, milk, cream, fruit, and vegetables. How many dealers between the farmer and the consumer. Look up the range of the birds which are winter residents. Make a list of important climatic records, such as dates of early snows, highest summer temperature, lowest winter record, depth of freezing of the ground, etc. Compare with other parts of the State and the Nation, drawing conclusions as to how the local agriculture is affected. Make a district survey of dairy cattle, including number on each farm, breeds, pure bred or scrubs, silos, sanitation, records kept, testing for butter fat, and feeding methods for each farm. (See Survey Form in Supplement VII.) Use both map and chart methods. Keep figures for arithmetic.

History.—Write to a dairy association for information about the history of dairying for the State, the story of modern scientific dairying, the Babcock test, the separator and clean milk. Trace the prodigal farming methods of the past and show how these must be modified in the near future. Find what great Americans have been reared on the farms. Show how the farmer must have great influence in the affairs of the Nation, also the necessity of his being well informed and broadly educated. Find the effect of seed selection and milk testing in sections which have tried them.

Drawing.—Have careful drawings made of ideal ears and kernels of corn. Working drawings or sections should be prepared while the milk tester is being explained and used. Have pupils make a sectional drawing of the separator in common use in the district showing working parts in place. Sketch the typical dairy cow and enlarge this to make a chart for class use in studying the points of the dairy cow. Sketch winter birds and winter scenes on the farm. Make plans for any constructive work at home. (Fig. 3.)

Physiology.—Apply to the care of hens and cows and other animals the principles learned in physiology concerning winter exercises, ventilation, exposure, etc. Show that undue protection renders any animal less resistant and when ventilation is limited at the same time colds and germ diseases are more easily contracted. Reasonably low temperature is to be feared less than poor ventilation. Show the value of vigorous exercise in the winter sports and work. Compare the habits formed by boys in doing chores with the training of farm

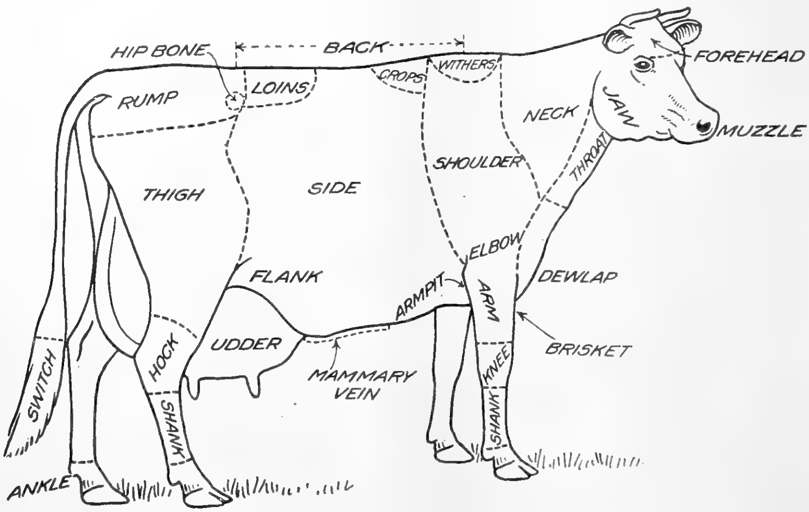

FIG. 3.—Chart of the ideal dairy cow. Approved by the Dairy Division, Bureau of Animal Industry.

animals. Take up now the part of the text on emergencies so far as they relate to winter conditions.

Manual training.—The practical exercises for this month suggest all the needed manual training related to agriculture. (See Farmers' Bul. 638.)

JANUARY.

Practical and field exercises.—Continue the work in milk testing and corn judging until some skill is attained. Those who are to hatch chickens should now separate with care the breeding fowls and give them ample room and suitable food. The testing of eggs and care of the market eggs are important from now on. (See Farmers' Bul. 562.) Each pupil should decide on what club work or home projects he is to take up during the coming season.

If it is advantageous in your district to haul the fertilizer in winter, take up that matter with each club member. Visit local factories and warehouses which deal with agricultural material of any sort.

Language lessons.—Stories of winter operations, trips, and pleasures offer much opportunity for oral and written language work. The snow and ice quicken local industries and provide new sports. Letters to obtain seed catalogues should be written this month. The pupils of this group should write about feeding cows or poultry, winter birds in the orchard, also reports on trips and observations. Write for State and Federal publications on the topics related to the club work of the coming spring.

Reading and spelling.—Use supplementary readings which are seasonal. Selections suggested as samples are Winter Time—Stevenson; Essay on Roast Pig—Lamb; The Forest Song—Venable; Winter—Lowell; Woodman, Spare That Tree—Morris; The Home Song—Longfellow.

Also select readings from Farmers' Buls. 173 and 358, A Primer of Forestry, in two parts; 363, The Use of Milk as Food; 594, Shipping Eggs by Parcel Post.

Misspelling, mispronunciation, and misuse of agricultural terms often arise from the same cause. Teach the spelling, pronunciation, and proper use of each word used and drill until the pupils acquire confidence in using them.

Arithmetic.—Use the records from milk testing combined with records of milk production and compute total yield of butter fat, money value, and estimated profit. Where feed records are available, obtain exact profit over cost of feed. Make similar computations from egg records and poultry feed accounts. Consult census or Yearbook records for comparison with local productions and also for further problems. Compute fertilizer needed on club fields and gardens. Find the volume and capacity in tons of ice houses. Measure logs, lumber, and woodpiles, and base problems on these figures. Use local prices and compute value of each. Have each club member keep accurate accounts. (See Farmers' Bul. 572.)

Geography.—Look up the origin and present source of various fertilizer ingredients, and consider which ones might be replaced by better farm practice. Compare dairy records of the State and various other States and nations as printed in farm papers. Have maps made of the home farms, and on them locate the pupils' own fields and each of the crops for the coming season as fast as they are decided. Locate by color or shading the different soils. The United States Department of Agriculture has issued soil surveys of many counties and some States have issued others. Obtain one for the county, if possible. Study the lumber industry of the section and the State, national forestry work, kinds of native woods, and imported lumber. What part does ice take in modern dairy farming? In storing and transporting produce? How does the South get its ice?

History.—Trace the development of the lumber industry in the State; the growth of the movement against deforestation and related conservation movements. The State forester has probably issued helpful information. Explain why early wasteful methods were used. Refer to great historical forests. Inquire into the history of the section regarding fertilizers and concentrated feedstuffs. What crops are now sold to buy these, and does it pay? Look up in State and local histories and stories the winter experiences of pioneer days and find how self-supporting the farm was. What modern methods are improvements? Are any of them the reverse?

Drawing.—Sketch farm animals which are involved in pupils' projects? Winter tree forms make good studies and lead to a better acquaintance with the trees of the district. Arrange these for future reference. Have some pupils sketch the tools used in some of the work inspected this month, as lumbering or ice-cutting tools.

Physiology.—Delvelop the following topics: Diseases and emergencies which are more common at this season; tuberculosis as a preventable disease; milk from tuberculous cows; milk and cream as absorbents and carriers of disease; prevention of epidemics; the laws of the State and the local health board rules. See Farmers' Buls. 363, The Use of Milk as Food; 473, Tuberculosis; 490, Bacteria in Milk; 602, The Production of Clean Milk.

Manual training.—Make egg testers and corn-testing apparatus ready for next month. Make models of stables, poultry houses, and sleeping rooms arranged for proper ventilation. Have girls cook and serve various apple dishes. Make bird houses. (See Farmers' Buls. 609 and 621.)

FEBRUARY.

Practical and field exercises.—Make definite plans for garden and other projects, taking up details. Order seeds needed in a quantity sufficient to allow testing. Make tests of corn and other seed at school, illustrating different methods of testing. (See Farmers' Buls. 428 and 617.) Have pupils continue this testing at home and ask them to report on this home testing. Make a study of the seedlings, referring to textbooks in botany. To obtain very early plants, sow seeds this month in hotbeds or window boxes. Continue testing eggs for marketing and ask pupils to practice this at home. It pays. Visit a creamery or other local establishment where eggs are tested and shipped. Hold a special public demonstration of the ability of the class to test milk, judge corn, test seeds for germination, etc.

This is a good time to hold a public spelling contest. Observe the bird movements which begin soon and keep a bird calendar. (Fig. 4.)

Language lessons.—Supervise the writing and sending of seed orders. Have the pupils write out their records and reports with care, making clearness of statement the first aim. Have copies made of some of the best reports and keep them with the files of agricultural literature. Have members of the class write invitations to adults requesting them to attend the contests. Have careful reports made of each new process taken up. Write letters to request new bulletins for spring work.

Reading and spelling.—Suggested supplementary readings include Happy the Man—Pope; The Home Song—Longfellow; The Arab to His Steed—Caroline Norton; To a Mouse—Burns; Stories of Morrill, Seaman Knapp, and of other men who have assisted agricultural education in the Nation or the State. Read some of the most recent laws on this subject. Also use in class Farmers' Buls. 218, The School Garden; 255, The Home Vegetable Garden; 445, Marketing Eggs Through the Creamery; 528, Hints to Poultry Raisers. Pay special

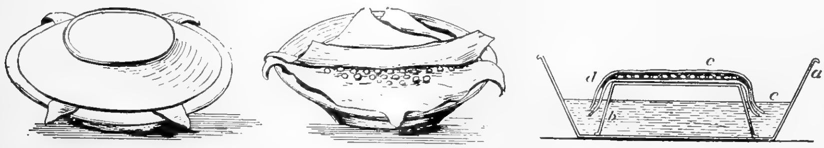

FIG. 4.—Germinating devices for garden seeds.

attention to the spelling of words used in the correspondence and reports sent out. Hold spelling contest and use all the farm words possible.

Arithmetic.—Practice making invoices, checks, receipts, and other commercial forms involved in farm business. Compute garden areas and lay out to scale the space for each variety of vegetable. Use problems based on egg sales, cost of marketing, and net income. Use the figures obtained in milk testing, compute value of butter fat per hundredweight of milk and total value of milk if 30 cents per hundredweight is allowed for skimmed milk. Get the milk records of some of these cows and compute total income. If possible, get feed records and combine these with the other problems.

Geography.—Add a district survey map covering the practice in seed testing, also in raising good seed. Have pupils look up the origin of the various seeds used in the district for garden and field crops. Should more seed be raised at home? Which of these crops grow wild in milder climates? Which garden crops would it pay to raise for near-by markets? Investigate the demand and the supply of these things which the club members of the class plan to raise. Carry this investigation to cities as far distant as shipment could be made.

What unfavorable conditions of soil or climate may prevent the success of some club projects?

History.—Have pupils look up (in reference books at home or in the library) the original home and the historical place of each of the crops to be raised in club or project work, recording the native land and the date when each became available for human food. Trace also the modern improvement. How are new vegetables brought into use? How many have been domesticated during the last century? What vegetables popular elsewhere are never raised here? Why?

Drawing.—A series of drawings to show the development of the germinating bean (or other seed) may be carried up to the opening of the true leaves. Make working drawings and bill for material for seed testers and seeding flats or shallow boxes. Make plan and pattern for an egg tester, also plans for suitable shipping cases for eggs. Draw school and home gardens to scale.

Physiology.—Study the State and local laws covering all matters of sanitation and discover what needs are not covered by legislation. Water supply, sewage, infectious diseases, clean milk, and other laws are included. Is the rural section as well protected by legislation as the city? What laws are there for the protection of the people from injury? Compare the different methods of heating homes in the section as regards effectiveness of heating and opportunity for ventilation. Criticise the school heating and ventilation. Use manuals issued by the State department of public instruction, also bulletins of the board of health.

Manual training.—Make seed testers and egg testers. Make window boxes and seed "flats," which is the common name for shallow boxes for starting seeds. Make model of hotbed or cold frames.

MARCH.

Practical and field exercises.—Prepare for incubation. Pupils should consider local climate, also their own facilities for indoor brooding before deciding on date for setting. Visit successful poultry plant to observe incubator practice. (See Farmers' Buls. 585 and 624.) Have a demonstration of how to preserve eggs. (See Farmers' Bul. 128.) Cold frames, if not already in use, must be prepared for seeds. Consult gardener's planting table. (See Farmers' Bul. 255, p. 46.) Start early plants of lettuce, tomatoes, asters, pansies, etc., under glass or in shallow boxes to be placed in windows. Have field demonstrations of grafting, pruning, and spraying as soon as the work can be done comfortably. Request the county extension representative of the State college to assist you in this. Set out fruit trees as early as the ground can be fitted. (For apple-club members.)

Language lessons.—Have prepared and mailed any necessary letters concerning club membership, seeds, fertilizers, or tools. Have pupils write a full report when they set a hen or start the incubator. Write and preserve reports of each field trip or demonstration, with full description of processes. Have either written or oral descriptions of work planned for the immediate future.

Reading and spelling.—Read some rural life selections like the following: The Homes of the People—Grady; The Plowman—Holmes; The Meadow Lark—Hamlin; Bluebird—Aldrich; Tubal Cain—Mackay; Out at Old Aunt Mary's—Riley; The Parable of the Sower—Bible. Use also bulletins and periodicals on the topics of current interest. Some Farmers' Bulletins of seasonal use (besides those previously referred to) are Nos. 516, The Production of Maple Sirup and Sugar; 585, Incubation of Hen's Eggs. Also consult the list of bulletins for those which concern special garden vegetables.

Arithmetic.—Material for problems will be found in poultry records, bills for seed, fertilizer and tools, cold-frame construction, orchard work, and dairy projects. The maple-sugar section has problems peculiar to that work. Develop the topic of taxation in the section, the method of assessing and its bearing on farm management. Find what correction of figures submitted with club projects might be needed to apply them to farm accounts in view of taxes, interest, and other fixed charges in the district and to show exact profit.

Geography.—Study the advantages and disadvantages of local climate in relation to early spring work on the farm. On a map draw lines to show the market radius for different local products. Use ink of another color and indicate sources of local purchases for farm supplies, especially those which might be produced locally. On the State map locate cooperative associations of farmers as creameries, breeders' associations, etc. Obtain information as to late spring frosts, safe dates for planting, transplanting, etc.

History.—Discuss the following topics in class after pupils have used reference books, local histories, and other texts: (1) Food supply and progress. The influence of transportation facilities. Such books as Brigham's From Trail to Railway Through the Appalachians, are helpful. (2) Local food supply and markets during early history. (3) The crops and industries as influencing the attitude of different States on great national issues. (4) Americans have invented and developed much machinery for raising and utilizing farm crops. Why? What machines? There are numerous books on inventions including such as Forman's Stories of Useful Inventions. Observe how man power is giving way to machine power in America faster than in Europe.

Drawing.—Use such sketching material as seedlings, bursting buds, a sugar camp, or some utensils. Draw tools used in grafting and pruning. Make diagrams for cold frame, trap nest, brood nest, or incubator. Have pupils draw those things they are about to use in club work or prepare careful drawings for booklet.

Physiology.—In connection with the plans for gardens and other projects take up the subject of foods and the desirability of variety of vegetable and fruit foods. Show how the action of digestive ferments renders available the starch in a germinating seed just as digestive fluids act in animals. Chapters on "germination" in botany explain this.

Start spring sanitary campaign to clean out cellars, dispose of rubbish, clean up and drain breeding places for flies and mosquitoes. See Farmers' Buls. 444, Remedies and Preventives Against Mosquitoes, p. 9; 459, House Flies; 535, Sugar and its Use as Food.

Manual training.—Make brood nests, "broody" coops, transplanting boxes, wooden garden labels. Repair cold frames and other equipment. Make suitable sample crates for shipping eggs sold by club members of the class.

APRIL.

Practical and field exercises.—Have suitable trips or demonstrations to illustrate methods of hatching and early brooding of chickens, also how to "break up" broody hens. Demonstrate transplanting of tomatoes and other plants started in the cold frames. Have the plowing and harrowing done for the club fields, except for late crops. Have a garden and crops survey of the district. Keep record of the returning birds, their habits and food. Plan and begin work on the improvement of the school grounds. Have pupils prepare bird houses. Plant out fruit trees, also shade trees around the home or the schoolhouse. Plan for next fall's exhibit before crops are planted.

Language lessons.—Continue written reports. Make records of all processes on the club work and any other projects. Such topics as the early care of chickens, starting my tomato plants, the birds about my home, are good topics. A tree-planting exercise gives rise to suitable language work. Have pupils write about the needs of the district and the possible remedies in view of the studies made. Strive for good conversational as well as written English.

Reading and spelling.—Select suitable readings, as That Calf—Alice Carey; The Barefoot Boy—Whittier; South Wind and Sun—Riley; The Song of the Sower—Bryant; April—H. H. Jackson; In the Heart of a Seed—Brown; The Bluebird—Emily Miller; Solomon and the Bees—Saxe.

Farmers' Buls. 154, The Home Fruit Garden; 195, Annual Flowering Plants; 287, Poultry Management; 537, Growing an Acre of Corn; 585, Incubation; 594, Shipping Eggs by Parcel Post; 597, The Road Drag and How It is Used; 609, Bird Houses and How to Make Them; 617, School Lessons on Corn; 624, Natural and Artificial Brooding of

Chickens; State bulletins and current articles should be used. Expect the most advanced pupils to be able to spell all the words appearing in the agricultural reading.

Arithmetic.—Have computations made in reference to the survey of the district, total areas for each crop, fertilizer used, expected crop at average yield, etc. Problems may be made based on observation of the birds and estimate of insect damage prevented by them. Use statistics for the State for crops in which the class is interested and arrange problems suited to the advancement of the pupils. Continue to use poultry, feed, and milk records, and especially the actual experiences on the home farms of the pupils.

Geography.—Have pupils search in newspapers and by personal inquiry locate the supply of eggs and poultry for the nearest large market. Determine the market radius of the local surplus. Locate on the map the chief producing areas and the large markets for tomato plants, ripe tomatoes, canned tomatoes, and other produce in which the class is interested. (See the latest Monthly Crop Report.) What sections market superior produce in these lines? What would be necessary to make the local produce as good? Would it pay to attempt to compete with the best on the market? Locate on district map each club member, using colored seals for different clubs.

History.—Develop the history of legislation intended to assist and encourage agricultural education, beginning with the Morrill Act in national legislation. (See the Circular on Federal Legislation relating to these topics, from the Office of Experiment Stations, United States Department of Agriculture.) Bring this study down to the present and show how State and Nation attempt to instruct in agriculture in schools and colleges and also on the farms. Show all the forces which are cooperating to help educate the young farmer and to assist him in other ways. Compare the history of the diminishing number of birds with that of increased loss from insect pests. Look up statistics on this topic.

Drawing.—Illustrate methods of transplanting small plants and fruit trees. Make working drawings of bird houses, garden markers, and other equipment to be constructed now or soon. Use actual club-work material.

Physiology.—Start a sanitary survey of the district. Include water supply, sewage disposal, fly and mosquito control, and other points in home sanitation. Include also the care of milk and food supply, the condition of the dairy, tuberculin testing, etc.

Have one lesson on the interrelation of plants and animals as regards oxygen and carbon dioxid, also in the utilizing of foods. Continue fly and mosquito topics.

Manual training.—Make bird houses, garden markers, and transplanting trays. Repair tools, trellises, and other things at the school.

Set out a tree on Arbor Day and construct a trellis to protect it. Make broody coop. Members of the Good Roads Club may make a road drag and begin to use it this month. (See Farmers' Buls. 597 and 638.)

MAY AND JUNE.

Practical and field exercises.—In apple-blossom time visit orchards to observe spraying for the codling moth. Complete planting and transplanting of all club crops and school gardens. Have practical demonstrations of methods of cultivating crops and of insect control. Arrange these with practical farmers. Continue the observation of birds in their relation to farm crops. Have demonstration of early feeding and summer care of chicks.

Language lessons.—Have pupils write reports on the planting and other early work on their projects. Write out also the reports on field trips and observations. Write a statement of things to be done during the summer, especially those processes which are new to the pupil. Have oral discussion of similar topics.

Reading and spelling.—Selections from good literature concerning rural life in summer are numerous. Only a few are here mentioned: The Farmer's Creed—Mann; The Pea Blossom—Anderson; A Song of Clover—Saxe Holm; Song of the Oriole—Howells; Blessing the Cornfield—Longfellow (Hiawatha); The Birds of Killingworth—Longfellow; A Day in June—Lowell.

Read also from suitable bulletins such as the following: Farmers' Buls. 113, The Apple and How to Grow It; 414, Corn Cultivation; 459, House Flies; 492, Insect Enemies of the Apple; 537, How to Grow an Acre of Corn.

The spelling lists for this season should cover the topics for summer work. The more advanced pupils should now spell correctly all ordinary agricultural terms.

Arithmetic.—Take up problems of plowing, harrowing, and planting. Find the cost of the crop up to this time including rent of land, fertilizer, seed, and labor. Numerous problems will arise in connection with the school and home gardens. The new flock of chickens will provide other problems. Make sure that each club member is keeping accurate accounts on each project and that each account is copied neatly for the report and booklet. In the apple club make accounts of the labor and material involved in pruning, spraying, cultivating, etc.

Geography.—Refer to bulletins and texts to find the origin of each of the common insect pests. How did they reach us? Notice how few appear to be native. Read in texts like Sanderson's Insect Pests of Farm, Orchard, and Garden. Do the same thing with weeds. Collect pictures of farm operations in foreign lands. Look up the location of canning factories for fruits and vegetables as sold in the local market. Locate these places on the map and consider the possibility of supplying the local market through the work of club members. Can these crops be raised and canned at a cost which will meet the competition of the factories? How about quality?

History.—Develop the history of methods of plowing, cultivating, and harvesting; the improvement of hand tools, followed by the substitution of machines. Refer to books on inventions and those on the industries. Show how much this development has meant to the country and how it has modified not only the method of work but also the distribution of crop acreage and the types of farming used. The story of the domestication of animals is a topic of interest. Davenport's Domesticated Animals and Plants will help.

Drawing.—Sketch apple blossoms in different stages, indicating at what stage to spray effectively. Sketch a codling moth. Draw parts of improved machinery and apparatus used. Complete the details in maps of gardens or farms as now being cultivated.

Physiology.—Take up the first aid in summer emergencies on the farm. Teach how to deal with ivy poison and other similar troubles the pupils may encounter. Use Farmers' Buls. 375, 459, and 540. Make a study of stable practice to control flies. Study the summer care of foods to prevent contamination and bacterial growth. (See Brewer's Rural Hygiene.)

Manual training.—Most of the manual work at this season should be done on the fields and gardens. If time permits it would also be well to make a fireless cooker and demonstrate its use. The girls should also have enough practice in the technique of canning to make sure they can do that part of the summer club work successfully. Complete all booklets as far as the progress of the club work will permit. Those which are complete may be bound with ribbon, cord, or metal fasteners.

CORRELATION SUPPLEMENTS.

I. THE SCHOOL EXHIBIT.

School exhibits or fairs of various kinds prove an incentive to pupils and compel the attention of the patrons of the school. The exhibit may not be an index of the quality of the school work, but an occasional exhibit of merit wins the recognition of the public and consequently at least a temporary interest in the work of the school. Of the possible exhibits related to agriculture the following may be mentioned:

(*a*) The school-garden fair. Produce of the school garden is suitably arranged for inspection and perhaps in competition. (*b*) Vegetables and flowers raised by pupils at home entered for school competition only. This may be at any convenient date. (*c*) A preliminary exhibit of pupils' produce when a part at least is to be exhibited in a county or other fair. This exhibit must necessarily be held early and extreme care must be used not to damage the specimens. (*d*) An exhibit where the pupils select the best they can find on the home farm and exhibit for the sake of illustrating the best. This is of value in communities where there is no regular agricultural fair. (*e*) Contests involving skill and judgment, such as corn judging, corn racking, etc. See Circ. 104 of the Bureau of Plant Industry, United States Department of Agriculture, Special Contests for Corn-club Work. (Fig. 5.)

In each exhibit or contest it is essential to have competent and impartial judges. The use of prizes should be judicious. Prizes of an agricultural nature are better than money, and in most cases ribbons or badges will serve as well. The cooking, canning, and sewing exhibits of the girls should be held at the same time, unless there is good reason for holding a separate exhibit. Have a poultry show in the early winter.

The exhibit and contest may be used to raise funds for some school improvement, and an auction sale of exhibits may be favored. In any case these events should make

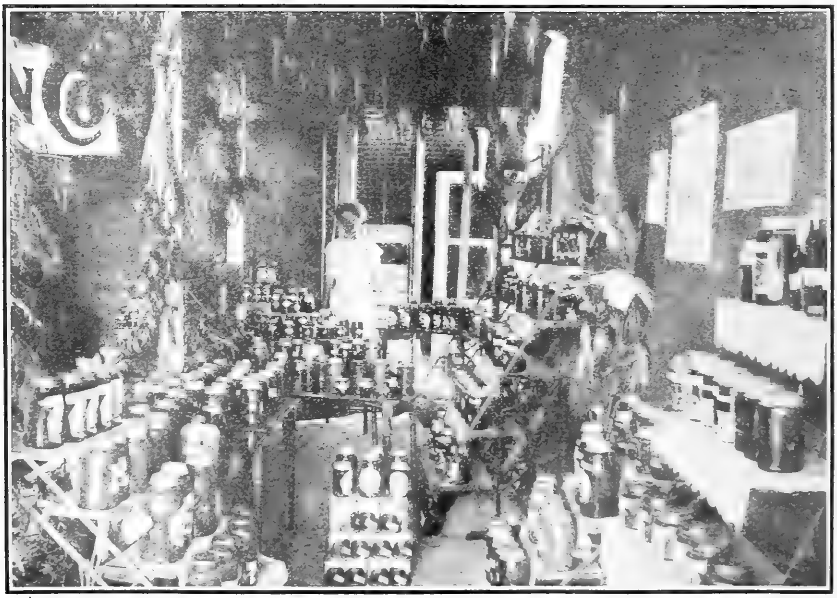

FIG. 5.—Pupils may make exhibit stands for a rural school.

the school a real community center. The initiative and artistic taste of the pupils may be used in such a way as to minimize the work for the teacher.

The local or county superintendent of schools and the county extension representative of the college of agriculture usually stand ready to assist a teacher in all such matters. This cooperation will also give sanction to the affair and modify the attitude of some parents.

II. SEED SELECTING.

Corn taken as a sample will illustrate method for other plants. Plants that are nearly ideal in form, size, and vigor which yield abundantly are liable to produce seeds which will reproduce these qualities. Selection of seeds from such plants in the field will, if persisted in for several years, improve the quality of the variety. Those qualities most desired may be increased by this means, while careless seed selection may have the opposite result. Crops are often doubled merely by careful selecting, curing, and testing of seeds.

(*a*) Select and mark before maturity more plants than is thought necessary. (*b*) Select from early maturing plants more seed than is needed. (*c*) Cure thoroughly, store safely in a dry place. (*d*) Test before planting season and discard ears or plants having low percentage germination. Refer to the instructions forwarded from United States Department of Agriculture through club leader in the State, also Farmers' Buls. 537, How to Grow an Acre of Corn, and 617, School Lessons on Corn.

III. SEED CURING AND STORING.

The importance of this is not generally appreciated in the North. In New England and northern New York to North Dakota not only do killing frosts come early in September in some years, but a freeze heavy enough to destroy the vitality of poorly dried seed is almost sure to come early in October. Seed corn at harvest time contains from 20 to 50 per cent water, and in case of freezing this water expands and destroys germination cells. The same water might, under other conditions, favor the heating or molding of the seed. For these and other reasons early selection and

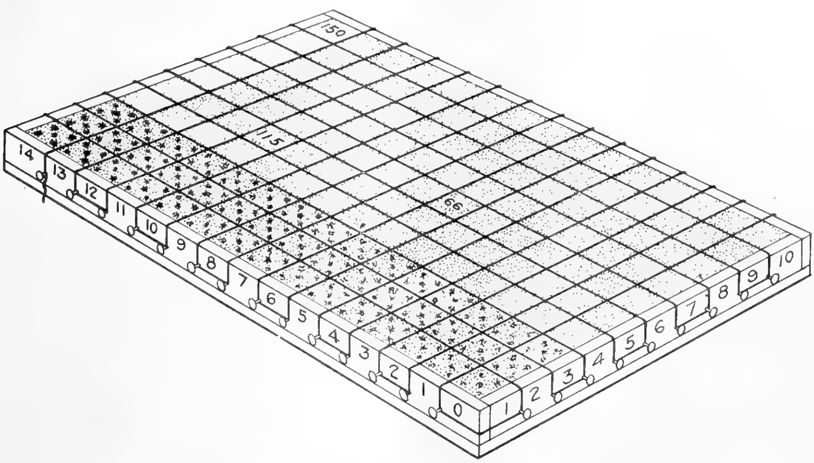

FIG. 6.—Sand tray for testing seed corn.

careful curing are very advisable.[1] (See Farmers' Bul. 537 and Bureau of Plant Industry Circ. 104.)

In storing remember (*a*) to keep seeds safe from mice and insects; (*b*) to keep dry, lest moisture absorbed cause premature sprouting or molding; and (*c*) to keep from excessive cold, as the moisture is never entirely dried out the first season.

Have drying and storing contrivances shown and their use demonstrated at school. Refer to Farmers' Buls. 229, 253, 313, 537, and 617.

IV. SEED TESTING.

In nearly all texts, manuals, and bulletins dealing with seeds the methods of testing seeds are explained and illustrated. This should come in late winter or early spring. Make it clear to pupils that two ears of corn may look equally good, and while one proves perfect in germinating power the other may show but a small percentage. Illustrate also the waste from low vitality in seeds which germinate but start too slowly. (Fig. 6.)

Illustrate different methods in school and use the sprouted seeds for related nature study. Continue some seedlings for further observation of cotyledons, leaves, etc.

[1] In 1914 a frost occurred as far south as Maryland, on September 14, which was severe enough in some places to damage immature seeds. Hence the same practice is advisable throughout the whole section and is imperative with late varieties.

Use corn, grain, and garden seeds. Rectangular box tester has its advantages, while the cloth roll is easily carried. Illustrate both. Detect weed seeds in small seeds. References—Bureau of Plant Industry Doc. 803 and Circ. 104; Farmers' Bul. 428.

V. PERMANENT EXHIBITS.

The limit to the extent of these exhibits lies in the space and protection possible. Insects, dust, mice, and careless children should be provided against at the outset lest discouragements follow. See Farmers' Buls. 586, plant-material exhibits; 606, insects, rocks, soils, etc.; 617, School Lessons on Corn.

Charts may be made of surveys of the district covering club interests, animals, crops, birds, etc. Charts in the form of maps of the district make graphic exhibits of local conditions. Colored seals may be used as indicators.

Pictures of famous or ideal animals, of typical plants and fruit, of model structures and equipment may be procured from periodicals. If they are mounted and filed away from the dust and sunlight, they will prove valuable in teaching.

VI. GARDEN PLANS.

The home or the school garden needs careful planning during the latter part of the winter. The success of the garden as well as its attractiveness may be insured by careful planning at an early date. What to plant must be first decided and then a chart arranged to scale having in mind area, sunlight, buildings, varieties, successions, and the possibility of horse cultivation. Beauty is possible even in the vegetable garden.

In the school garden make individual plats run so that summer cultivation may run through the whole area. If any demonstration is attempted, get the cooperation of some farmers. (See Farmers' Buls. 154, 220, 254, and 255.)

VII. A DISTRICT SURVEY.

A district survey may be similar to a census, but the aim should be to learn more about the community and to obtain interesting material for school work. Eventually the district will profit by these surveys. Take up but few points for one investigation, ask the pupils to cover definite portions of the district faithfully, and after the data are collected tabulate and compute interesting results. Whenever this material can well be shown on the map make such a survey map of the district to file with the tabulated chart. Where any valuable conclusions can be drawn allow them to be made public unless ill feeling may be caused. Keep charts covering the club work constantly up to date. These charts will vary much in character in different localities, but the samples here given will illustrate the idea. Along some lines a township, county, or State survey chart may be of value. Obtain heavy paper for survey, similar to manila paper used to wrap tobacco or heavy merchandise. The size should be 18 by 24 inches or larger. Make maps of district this size also for survey work. Sample survey forms are here given.

DISTRICT CORN SURVEY FOR SEPTEMBER.

Year............

(Other crop surveys may be made with modifications of this form.)

District................................ Teacher................................

Township.............................. Pupils' survey committee.............

County and State...................... ....

....

No.	Name of farmer.	Location.	Acres in farm.	Acres of corn.	Yield.	Yield per acre.	Variety.	Acres of silage.	Seed selection.
1									
2									
3									
Etc.									

DAIRY COW SURVEY OF DISTRICT.

Date............

(Other animal surveys may be made with modifications of this form.)

District................................ Teacher................................
Township............................. Pupils' survey committee.............
County and State...................... ....
....

No.	Farmer.	Location.	Number of cows.	Breed.	Pure or grade.	Average value.	Average weight of milk.	Disposal of milk.	Test milk.	Balanced rations.
1........	....	....	....	....	....	....	....	....	....	....
2........	....	....	....	....	....	....	....	....	....	....
3........	....	....	....	....	....	....	....	....	....	....
Etc.....	....	....	....	....	....	....	....	....	....	....

A DISTRICT ORCHARD SURVEY.

Date............

District................................ Teacher................................
Township............................. Pupils' survey committee.............
County................................. ....
....

Farmer.	Area of orchard.	Number of trees.	Age of trees.	Condition.	Last crop.	Price.	Value of crop.	Actual sales.	Spraying.	Labor, etc.	Net income.
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....

VIII. THE BOOKLET.

Each contest or project in the club work calls for a booklet which shall include a description of every phase of the work, a plan of the field or diagrams of equipment, drawings which illustrate material, process or products, and everything of interest relating to the project.

The paper should preferably be suited to ink and drawings may be inserted on drawing paper. The size of the sheet should not be so small as to cramp the writing and drawings. The covers may be of bristol board or other types of board used for mounts. If the surface is reasonably smooth cover drawings may be made directly on it; in other cases a drawing or photograph may be mounted as a part of the cover design. These drawings often furnish the best type of work for the drawing class, and the work of mounting pictures, binding with ribbon, cord, or metal fasteners gives opportunity to develop artistic taste. The booklet may be easily correlated with language, arithmetic, geography, and history.

The literature furnished by the State leader of club work or county superintendent may suggest various booklets.

IX. THE SCHOOL LIBRARY.

At little or no expense much valuable agricultural literature may be added to the school library.

From the United States Government:

1. The list of available Farmers' Bulletins will be sent as often as issued to the school address. Apply to the Editor and Chief, Division of Publications, United States Department of Agriculture, Washington, D. C. He will also send regularly

the Monthly List of Publications if requested. This gives information as to new publications.

2. So long as the supply lasts, Farmers' Bulletins may be had free from any Congressman or from the United States Department of Agriculture direct.

3. The Superintendent of Documents, Government Printing Office, Washington, D. C., will furnish free the price lists for Government publications on various topics, including agriculture. Many of these are sold at a purely nominal price, but it rarely ever pays to purchase those of a technical nature.

The State agricultural college and experiment station should furnish you free—

4. A list of available publications.

5. Copies of popular and extension bulletins dealing with subjects of local and State interest.

6. The State club leader or county superintendent should furnish copies of printed and multigraphed information sent out through the extension service of the college of agriculture.

7. Cattle registry associations publish bulletins or booklets on particular breeds. Manufacturers of farm machinery and fertilizer companies often issue valuable booklets, and these are usually free on request.

8. Farm papers and magazines often give special inducements to schools. In other cases these may be brought from homes after they have been read there.

9. The teacher should seek competent advice before purchasing books, as the limited funds should be made to cover the most valuable books first.

10. Filing boxes for bulletins may be made by remodeling pasteboard boxes and reinforcing the corners and backs. Arrange either by subjects or numerically in sets, using an index. Arrange photographs or other illustrations in a similar way.

Have the pupils individually write requests for such material as is needed in duplicate for class use. For library purposes use the name of the school or office rather than a person's name for the mailing list.

X. AVERAGE FOOD COMPOSITION OF SOME CLUB PRODUCE.[1]

Kind of food materials.	Refuse.	Water.	Total indigestible nutrients.	Digestible nutrients.				Fuel value per pound.	Nutritive ratio.
				Protein.	Fat.	Carbohydrates.	Ash.		
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*	*1:*
Poultry, fowls	25.9	47.1	1.2	13.3	11.7	....	0.5	765	2
Eggs, uncooked	11.2	65.5	1.1	12.7	8.8	....	.7	635	1.7
Whole milk	....	87.0	.5	3.2	3.8	5.0	.5	310	4.3
Butter	....	11.0	4.9	1.0	80.8	....	2.3	3,410	....
Corn meal	....	12.5	3.3	7.8	1.7	73.9	.8	1,640	10.0
White wheat bread	....	35.3	2.9	7.8	1.2	52.0	.8	1,200	7.0
Beans, white, dried	....	12.6	7.9	17.5	1.6	57.8	2.6	1,520	3.5
Potatoes	20.0	62.6	1.2	1.5	.1	14.0	.6	295	9.5
Tomatoes	....	94.3	.5	.7	.4	3.7	.4	95	6.6
Apples	25.0	63.3	1.2	.3	.3	9.7	.2	190	34.7

[1] Based upon Farmers' Bul. 142. Consult also Farmers' Buls. 22, 121, 182, 183, 249, 293, 295, 359, 363, 413, 535, 565.

XI. SPELLING SUPPLEMENT.

A county superintendent found that none of the textbooks in spelling used in his county contained any of the following list of words used in the rural school agriculture. Each teacher should compile his own list.

Elementary agriculture: Rootstock, fertilizer, nitrogen, tillage, fungous, fungicide, insect, ration, scion, osmosis, bacteria, silage, environment, grasshopper, onion, parasite, vegetable, tubercles, propagation, codling moth, weevil, alfalfa, legumes, biennials, pollination, hybrids, cankerworm, girdler, irrigation, horticulture, stigma, pigweed, perennials, Bordeaux, shredder, bulletin, Clydesdale, Guernsey, aphis, formalin, maize, nutritious, experiment, Aberdeen, bacillus, bindweed, dandelion, cockroach, burdock, laurel, sumac, hackney, Wyandotte, gallfly, cocklebur, ladybird, purslane, Percheron, Galloway, Plymouth Rock.

Home economics: Materials, basting, napery, overseaming, percales, muslin, stitching, overcasting, embroidery, dimities, cashmere, taffeta, digestible, tablespoonful, recipes, serviceable, fabrics, cupfuls, croquettes, proteids, albumin, gelatinous, pasteurize, utensils, preservative, ingredients, chocolate, sterilize, putrefaction, cinnamon, chemistry, economy, rhubarb, carbohydrates, ginghams, beverages, coagulation, braising, nitrogenous, cheviot.

XII. ADDRESS LIST OF STATE INSTITUTIONS AND OFFICERS IN CHARGE OF AGRICULTURAL EXTENSION WORK UNDER THE SMITH-LEVER ACT.

Northern and Western States, 1915.

Institution.	Officer.
Col. of Agr., Univ. of Ariz., Tucson, Ariz	S. F. Morse, Supt. of Ext.
Col. of Agr., Univ. of Cal., Berkeley, Cal	Warren T. Clarke, Prof. Agr. Ext.
State Agr. College of Colo., Fort Collins, Colo	C. A. Lory, Act. Dir. Ext. Serv.
Connecticut Agr. College, Storrs, Conn	H. J. Baker, Dir. Ext. Serv.
Delaware College, Newark, Del	H. Hayward, Dir. Ext. Serv.
Col. of Agr., Univ. of Idaho, Boise, Idaho	O. D. Center, Dir. Ext. Work.
Col. of Agr., Univ. of Ill., Urbana, Ill	W. F. Handschin, V. Dir. Agr. Ext.
Purdue University, La Fayette, Ind	G. I. Christie, Supt. Agr. Ext.
Iowa State College, Ames, Iowa	R. K. Bliss, Dir. Ext.
Kansas State Agr. Col., Manhattan, Kans	J. H. Miller, Dean Div. Col. Ext.
Col. of Agr., Univ. of Maine, Orono, Me	L. S. Merrill, Dir. Agr. Ext.
Massachusetts Agr. College, Amherst, Mass	W. D. Hurd, Dir. of Ext. Serv.
Michigan Agr. College, East Lansing, Mich	R. J. Baldwin, Supt. of Ext.
Col. of Agr., Univ. of Minn., Univ. Farm, St. Paul, Minn	A. D. Wilson, Dir. Ext. and F. I.
Col. of Agr., Univ. of Missouri, Columbia, Mo	A. J. Meyer, Sec'y of Agr. Ext.
Montana State College, Bozeman, Mont	F. S. Cooley, Dir. Ext. Serv.
Col. of Agr., Univ. of Nebr., Lincoln, Nebr	C. W. Pugsley, Dir. Agr. Ext. Serv.
Col. of Agr., Univ. of Nevada, Reno, Nev	C. S. Knight, Dir. Agr. Ext.
N. H. Col. of A. and M. Arts, Durham, N. H	J. C. Kendall, Dir. Ext. Work.
Rutgers Scientific School, New Brunswick, N. J	Alva Agee, Dir. Div. of Ext.
N. Mex. Col. of A. and M. Arts, State College, N. Mex	A. C. Cooley, Dir. Ext. Work.
N. Y. State College of Agr., Ithaca, N. Y	B. T. Galloway, Dir. Div. Ext.
N. Dak. Agr. College, Agricultural College, N. Dak	T. P. Cooper, Dir. Ext. Work.
Col. of Agr., Ohio State Univ., Columbus, Ohio	H. C. Price, Dir. Agr. Ext. Work.
Oregon State Agr. College, Corvallis, Oreg	R. D. Hetzel, Dir. Ext. Work.
Pennsylvania State College, State College, Pa	M. S. McDowell, Dir. Agr. Ext. Work.
Rhode Island State College, Kingston, R. I	A. E. Stene, Dir. Ext. Serv.
S. Dak. State College, Brookings, S. Dak	E. C. Perisho, Act. Dir. Ext.
Agr. College of Utah, Logan, Utah	E. G. Peterson, Dir. Agr. Ext. Div.
Col. of Agr., Univ. of Vermont, Burlington, Vt	Thos. Bradlee, Dir. Ext. Serv.
State College of Washington, Pullman, Wash	J. A. Tormey, Dir. Ext. Div.
Col. of Agr., Univ. of Wis., Madison, Wis	K. L. Hatch, Asst. Dir. Agr. Ext.
Col. of Agr., Univ. of Wyo., Laramie, Wyo	A. E. Bowman, Dir. Ext. Work.

XIII. SUGGESTIVE PROBLEMS IN ARITHMETIC.

The teacher should adapt the problems to the advancement and current topics in arithmetic for the class in question. On the other hand, the numbers to be used as well as the subject matter may be found in the projects of the pupils or in the reference readings on these projects.

New textbooks are constantly appearing which contain agricultural problems, and among those now in print are Burkett and Swartzel's Farm Arithmetic, Calfee's Rural Arithmetic, and Nolan's One Hundred Lessons in Agriculture.

SEPTEMBER.

1. Have the pupils prepare a few poles or other measures a rod long and mark off yards and feet on each. Measure the school garden and the school yard and compute the area of each.

2. Use these poles or lines to measure the fields of club members, computing the area of each.

3. On a field of corn used for seed selection, measure off two average yield areas exactly a rod square. Count the stalks on these areas and compute the stand per acre. Also count ears of corn.

4. On a plat of tomatoes (one-tenth of an acre) the rental was $2, labor $4.50, staking and pruning $2, fertilizer $2.50, harvesting $2. One hundred dozen cans at 36 cents a dozen were used. The canner cost $5 and the cost of labor for canning was $10. The output of 1,200 cans sold at 8 cents a can. Find cost of production, total cost in cans, profit, percentage of profit based on investment, and profit per can.

5. A round silo has an inside diameter of 14 feet and is filled to the height of 32 feet. Find volume in cubic feet and weight of silage in tons if each cubic foot weighs 38 pounds. How many days' feed will it hold at 35 pounds a day for each cow, and how many cows will it feed for 180 days?

OCTOBER.

1. The floor plan of a club member's poultry house measures 20 feet long by 14 feet wide. Deduct 112 square feet for equipment and find the floor space per hen for a flock of 32.

2. This same house has a shed roof and stands 8 feet high in front and 5 feet at the rear. Compute the area of each side and end, also of the roof, allowing an extension of 1 foot on front and back over the walls. Compute boards for sides, roof, and floor, add one-half to cover the frame timber, and then make out a bill at the local prices.

3. Similar problems may be arranged concerning a hog house whenever pig-club members are in the class.

4. On a club acre 6,125 pounds of ear corn is harvested which has 18 per cent to be deducted. Compute bushels of ear corn, 70 pounds a bushel. When shelled each bushel weighs 56 pounds, what percentage of the ear corn is cob? Find value of this yield at 68 cents a bushel.

5. Farmers' Bul. 409, page 11, states that when $10 worth of corn is sold off the farm $3.78 worth of fertilizer is sold, but in selling $10 worth of beef cattle only $1.18 worth of fertilizer is sold. Compute the saving by turning the corn crop of problem 4 into beef, allowing for no other change of values.

6. In one feeding experiment it took 6 pounds of corn to produce 1 pound gain of pork. At the present market prices would this pay? What percentage of gain or loss if the corn were bought?

NOVEMBER.

1. A pen of 25 hens costing 55 cents each lay an average of 117 eggs a year, valued at 19 cents a dozen. Care and feed costs 21 cents per month each hen. Find net profit for the flock, allowing 50 cents for meat value of each hen at the end of the year.

2. By substituting pure-bred hens at $1 each and increasing the feed cost 6 cents each per month, 186 eggs per hen were obtained, averaging 28 cents a dozen. Find the total gain and the percentage profit on added investment over problem 1.

3. A pupil sets an orchard of apple trees on a square acre, trees to be set 2 rods apart each way and none to be nearer than 1 rod to either boundary. Find cost if trees sell at $22 a hundred and labor is 9 cents a tree.

4. An older orchard of the same area is sprayed with lime-sulphur in November for San José scale at a cost of 28 cents a tree. The apparent gain next fall is an increase of 45 bushels of marketable fruit at $4.50 a barrel. Find net gain due to spraying.

5. A mixture of 200 pounds of cracked corn, 360 pounds of wheat, 130 pounds of oats, is fed to a flock of 35 hens at the rate of 4 pounds a day. At local prices compute cost per hen per day for this scratch feed.

DECEMBER.

1. While judging corn count the kernels on each row of the best ear found. If by improvement one kernel could be added to each row, what percentage of increase would this give?

2. If but 80 per cent of the seed of this best ear would germinate, what loss would result, supposing each kernel should yield an ear and 85 ears to make a bushel, corn selling at 72 cents a bushel?

3. What loss at this rate on an acre which would have produced 95 bushels from good seed?

4. A cow produced in one year 8,465 pounds of milk containing 421 pounds of butter fat. Find the percentage of butter fat.

5. In the stomach of one woodpecker 28 white grubs were found. If the bird had continued to eat this number each day for the month of October, compute the value of the bird in a potato field, assuming that each grub would have ruined one 4-ounce potato. Call potatoes 50 cents a bushel.

6. A quail in December was known to consume for one day over 2,000 May weed seeds. Estimate that each 10 weed seeds might have cost one ear of corn the next year and that 85 ears make a bushel. Compute the loss prevented by 10 quails at this rate during the entire month of December.

JANUARY.

1. A club member reports the average daily milk production of his father's cows as 11, 13, 17, 20, 26, and 30 pounds. What is the total for each cow for 300 days? At $2.10 per hundredweight compare the best cow with the poorest.

2. The milk for the same cows as tested for butter fat by the boy shows 4.9, 4.1, 5.1, 3.8, 3.4, and 3.6 per cent, respectively. Find total butter fat for each cow and value at an average of 27 cents a pound for the year.

3. Because of these tests, cows Nos. 1, 2, and 4 are sold and new cows bought producing 24, 29, and 34½ pounds of milk, testing 5.2, 4.7, and 3.5 per cent butter fat, respectively. Find apparent yearly gain due to this exchange, butter fat being worth 27 cents a pound.

4. By using more care in feeding the same herd a ration costing but two cents a day more per cow results in an average increase of 4 pounds of milk a day. What profit results during a year?

5. During a State test for one year the Holsteins averaged 14,688.8 pounds testing 3.42 per cent, the Guernseys 8,465.4 pounds testing 4.98, and the Jerseys 7,046.7 pounds testing 5.16. Find annual value for each breed of market milk at $1.40 per hundredweight, also of butter fat at 25 cents a pound.

6. At what price per hundredweight must milk testing 4.9 per cent be sold to equal 27 cents for butter fat, allowing 30 cents per hundredweight for skim milk?

FEBRUARY.

1. Find the percentage of loss occasioned by putting one poor egg in a 5-dozen case and having them rated as seconds at 29 cents instead of firsts at 35 cents a dozen.

2. By testing a 30-dozen case of eggs and discarding six eggs a boy received 5 cents a dozen more on what remained. This was a 20 per cent gain on those sold. Find total receipts.

3. About 15,000,000 bushels of seed corn are used in this country, of which 86.3 per cent is good. How many bushels should be rejected for better?

4. It has been estimated that the rejection of the poor seed would have increased the average yield 298,140,695 bushels, or 13.7 per cent. Find the average yield.

5. A girl is to raise one-eighth of an acre of tomatoes and will use a part of a field which is 15 feet wide. How long a strip will she use? How many plants can she set 3 feet apart each way?

6. Refer to Farmers' Bul. 22 and compute from the local feeds available a good ration for a 1,000-pound cow producing 22 pounds of milk. At the current prices compute the cost of this ration.

MARCH.

1. A farm of 125 acres is valued at $16,000 in a township where taxes are $1.50 on $100 and interest on good security is 5 per cent. What minimum rent on a club acre would be necessary to cover interest and taxes?

2. Compute the number of hills in an acre of corn planted according to club directions. If there are 1,400 kernels of corn in a pound, how many pounds will be needed to plant the club acre, if it is tested well?

3. An average of two and one-half hours a tree, at 25 cents an hour, is spent in pruning 37 trees. How many more apples at $3.50 a barrel will be needed to pay for this work?

4. If it costs 9 cents extra per dozen to trap-nest eggs for setting, what percentage of extra profit is there in selling setting eggs at $2 per 15 eggs instead of at 30 cents a dozen for market?

5. Make out a bill of lumber for a cold frame to be covered by two 3-foot by 6-foot sash, the walls to be boarded $2\frac{1}{2}$ feet on the north side and 2 feet on the south. Add 20 per cent for waste; bill lumber at $30 per M, and allow 12 cents for nails and $1.90 each for sash. Receipt the bill properly.

6. How many tomato plants may be started in the cold frame in problem 5, allowing $2\frac{1}{2}$ inches each way for each plant?

APRIL.

1. A club member pays $7.20 for seed potatoes for his half-acre, $18 for fertilizer, 54 cents for plowing, $2.16 for planting, $1.44 for cultivating, $5.76 for spraying, $3.60 for harvesting and sacking. The yield is 91 bushels. It cost 7 cents a bushel to get them to market and the commission man returned to him 59 cents a bushel. Find the net profit.

2. How much would this boy have gained by selling direct to the retailer and dividing the middleman's profit? The retailer paid $1.25 a bushel.

3. Compare results on a half acre for early potatoes yielding 120 bushels an acre to sell at $1.30 as compared with late potatoes producing 185 bushels and selling at 55 cents. Are there other advantages in either plan?

4. A fertilizer formula, as 2 : 8 : 2 indicates the percentages of the entire weight available for plant use as nitrogen, phosphorus, and potash, respectively. Find how many pounds of each in 1 ton (2,000 pounds) of fertilizer with the above formula.

5. When nitrogen is worth 15 cents a pound, phosphorus 4 cents, and potash 7 cents, find the fertilizing value of 1 ton of 2 : 8 : 4.

6. Much of the nitrogen can be provided by crops like clover and alfalfa. What is the money saving per ton on each per cent of nitrogen thus saved? What gain when 2 per cent extra nitrogen on 1 ton fertilizer increases the yield of timothy hay one-half ton? Use local prices. (Use Farmers' Bul. 44.)

MAY AND JUNE.

1. Arsenate of lead costing 17 cents a pound is suspended in water, about 5 pounds in 50 gallons of water. If a 50-gallon tank full will spray 9 trees at a cost of 40 cents for labor, how much will it cost to spray three times an orchard of 25 trees?

2. Bordeaux mixture consisting of 6 pounds of copper sulphate at 8 cents a pound and 4 pounds of lime at 1 cent a pound in each 50 gallons of water is used to spray potatoes three times. If it takes 30 gallons for once over the field and the labor is 75 cents each time, find the cost of spraying.

3. The crop in the field in problem 2 was increased 63 bushels apparently because of spraying. What was net gain if potatoes sell at 55 cents a bushel?

4. One ton of clover contains 40.16 pounds of nitrogen, 11.2 pounds of phosphorus, and 36.6 pounds of potash. Find the fertilizing value of one-half ton plowed down on an acre. Use process given before.

5. A field drained at a cost of $150 gives an increased yield of 4 tons of hay, valued at $16.50 a ton, the first year. How many years at this rate will be needed to pay back the investment, paying 6 per cent interest at the same time?

XIV. SCORE CARDS TO ASSIST TEACHERS.

Many of the State colleges of agriculture through their extension service furnish to teachers a limited supply of score cards. In such cases the teachers should procure the blanks adapted to their States. The following scores were selected from those used in the Northern and Western States, and so far as possible the most common type was chosen. In case of diversity the card chosen was the most teachable form found. The teachers should use these more for standards of excellence in club work, but a limited number of judging exercises may be held on the crops or animals of local importance.

SCORE CARD FOR POTATOES.

Variety name .... Exhibit No. ......

Points.	Perfect.	Scorer's.	Corrected.
Uniformity of exhibit	20	....	....
Trueness to type	10	....	....
Shape of tuber	15	....	....
Size of tuber, 4 to 8 ounces	15	....	....
Eyes, as affecting paring	5	....	....
Skin: Color, thickness, toughness	5	....	....
Texture of tuber	5	....	....
Soundness	10	....	....
Freedom from blemishes	15	....	....
Total	100	....	....

Remarks..

Name of scorer.................................. Date ....

SCORE CARD FOR CORN.

Variety.. Exhibit No. ......

Points.	Perfect.	Scorer's.	Corrected.
Maturity and seed condition. To be of value for grain, corn *must* mature and produce good, hard seed.	25	....	....
Uniformity. Ears should be alike in shape, size, color, indentation, and size of kernel.	15	....	....
Kernels. Flat side, slightly wedge-shaped with large, smooth germ. Edge, with parallel sides and of medium thickness. Not chaffy.	15	....	....
Weight of ear. Dent varieties, as usually planted, produce only one ear per stalk, hence yield per acre depends largely upon weight of shelled corn per ear.	15	....	....
Length and proportion. Varies with locality and variety. Experiments show that a continued selection of short, thick ears reduces the yield.	10	....	....
Butts. The base of the ear should be covered with even-sized kernels in straight rows which are a continuation of those at the center of the ear. The shank should be large enough to support the ear and no larger.	5	....	....
Tips. Should be covered with kernels of the same depth as and in rows which are a continuation of those at the center of the ear.	5	....	....
Space between rows. Should be very slight and in straight lines.	5	....	....
Color. The color of both grain and cobs should be uniform, showing trueness to type or strain.	5	....	....
Total	100	....	....

Remarks..

Name of scorer.................................. Date ....

SCORE CARD FOR VEGETABLES.

Vegetable.. Variety..........
Class.. Exhibit No. ......

Points.	Perfect.	Scorer's.	Corrected.
Uniformity	20		
Symmetry	15		
Quality	15		
Texture	10		
Freedom from blemishes	15		
Commercial or table value	25		
Total	100		

Remarks...
Name of scorer.................................. Date ....

SCORE CARD FOR HOME GARDEN.

Garden No.................... Location....................................

Points.	Perfect.	Scorer's.	Corrected.
Location and soil[1]	5		
Number of varieties Reasonable range	10		
Garden plan	10		
Evidence of cultivation	20		
Tillage tools[1]	5		
Freedom from weeds	10		
Health of vegetables	15		
Yield, computed from fixed scale of values	25		
Total	100		

[1] With adults or older pupils having a choice in location and tools, these items are of more relative importance.

Remarks...
Name of scorer.................................. Date.................

SCORE CARD FOR TOMATO PLANT.

Variety.. Exhibit No. ....

Points.	Perfect.	Scorer's.	Corrected.
Form	10		
Vigor	25		
Foliage	10		
Product (quantity and quality)	35		
Disease (plant and product)	20		
Total	100		

Remarks...
Name of scorer.................................. Date.................

SCORE CARD FOR TOMATOES—PLATE.

Variety... Exhibit No. ....

Points.	Perfect.	Scorer's.	Corrected.
Shape (should be ideal for variety)	15		
Blow or blossom end (small scar and smooth)	10		
Stem end (small, slight depression)	10		
Color (uniform and ideal for variety)	15		
Flesh (solidity)	10		
Flesh (uniform color)	10		
Even ripening for individual fruits	15		
Uniformity of sample	15		
Total	100		

Remarks...

Name of scorer.................................... Date...................

SCORE CARD FOR APPLES—BOX PACK.

Variety .... Exhibit No. ......

Points.	Perfect.	Scorer's.	Corrected.
Fruit, 65 points:			
Texture and flavor	10		
Value of variety	10		
Size	10		
Color	10		
Uniformity	10		
Freedom from blemishes	15		
Package, 5 points:			
Material	3		
Marking	1		
Solidity, nailing, cleats, etc	1		
Packing, 30 points:			
Bulge or swell	5		
Alignment	4		
Height at ends	5		
Compactness	8		
Attractiveness or style of pack	8		
Total	100		

Remarks...

Name of scorer.................................... Date ....

SCORE CARD FOR APPLES—PLATE.

Variety... Exhibit No. ......

Point.	Perfect.	Scorer's.	Corrected.
Size (Normal: Neither too large nor too small)	10		
Color, typical	25		
Freedom from blemish	20		
Texture and flavor	20		
Uniformity and trueness to type	25		
Total	100		

Remarks...

Name of scorer.................................... Date ....

SCORE CARD FOR ALFALFA HAY.

Class.. Exhibit No. ......

Points.	Perfect.	Scorer's.	Corrected.
Color: Bright green preferred; brown, in sweated sample not objected to..	16	....	....
Smell: Fresh, sweet, appetizing; free from mustiness..........................	20	....	....
Fineness of stem..	8	....	....
Softness of stem: Pliant, not harsh or brittle...........................	8	....	....
Percentage and condition of leaf......................................	14	....	....
Purity: Proportion of alfalfa as compared with grasses, etc..............	8	....	....
Cleanness: Freedom from dust, molds, objectionable weeds, etc..........	18	....	....
Weight and general makeup for market..................................	8	....	....
Total..	100	....	....

Remarks...
Name of scorer..

SCORE CARD FOR DAIRY CATTLE.

Breed..................... Name..................... Register No. ....

General appearance.—A dairy cow should weigh not less than 800 pounds, have large capacity for feed, a dairy temperament, well developed milk organs, fine quality and perfect health, and be capable of a large production of milk and butter fat.

Points.	Perfect.	Scorer's.	Corrected.
Indication of capacity for feed, 25 points:			
Face, broad between the eyes and long; muzzle clean-cut; mouth large; lips strong; lower jaws lean and sinewy..................................	5	....	....
Body, wedge shape as viewed from front, side, and top; ribs long, far apart and well sprung; breast full and wide; flanks, deep and full...	10	....	....
Back, straight; chine, broad and open; loin, broad and roomy.......	5	....	....
Hips and thurls, wide apart and high...................................	5	....	....
Indication of dairy temperament, 25 points:			
Head, clean-cut and fine in contour; eyes, prominent, full, and bright.	3	....	....
Neck, thin, long, neatly joined to head and shoulders, and free from throatiness and dewlap..	4	....	....
Brisket, lean and light..	2	....	....
Shoulders, lean, sloping, nicely laid up to body; points prominent; withers sharp..	4	....	....
Back, strong, prominent to tail head and open jointed................	3	....	....
Hips, prominent, sharp and level with back............................	3	....	....
Thighs, thin and incurving...	4	....	....
Tail, fine and tapering...	1	....	....
Legs, straight; shank fine..	1	....	....
Indication of well-developed milk organs, 25 points:			
Rump, long, wide, and level; pelvis roomy..............................	3	....	....
Thighs, wide apart; twist, high and open	3	....	....
Udder, large, pliable, extending well forward and high up behind; quarters, full, symmetrical, evenly joined, and well held up to body.	15	....	....
Teats, plumb, good size, symmetrical, and well placed................	4	....	....
Indications of strong circulatory system, health, vigor, and milk flow, 25 points:			
Eyes, bright and placid..	2	....	....
Nostrils, large and open..	3	....	....
Chest, roomy...	5	....	....
Skin, pliable; hair, fine and straight; secretions abundant in ear, on body, and at end of tail..	7	....	....
Veins, prominent on face and udder; mammary veins, large, long crooked, and branching; milk wells large and numerous..............	7	....	....
Escutcheon, wide and extending high up................................	1	....	....
Total..	100	....	....

Remarks...
Name of scorer................................ Date..........................

SCORE CARD FOR SWINE.

Breed........................ Name.................. Register No. ......

Points.	Perfect.	Scorer's.	Corrected.
General appearance, 25 points:			
Weight, ...; estimate, ...; actual pounds	6	....	....
Form, deep, broad, low, long, symmetrical, compact, standing squarely on legs	8	....	....
Quality, bone clean; hair, silky; skin, soft; head and ears, refined, evenly covered with firm flesh	6	....	....
Disposition, quiet, docile	5	....	....
Head and neck, 10 points:			
Snout, medium length, not coarse	1	....	....
Face, short, cheeks full	1	....	....
Forehead, broad	1	....	....
Eyes, large, mild, full, bright, wide apart	1	....	....
Ears, medium size, fine, soft	1	....	....
Jowl, strong, neat, broad	2	....	....
Neck, thick, medium length	3	....	....
Fore quarters, 13 points:			
Shoulder, symmetrical, broad, deep, full, compact on top	6	....	....
Breast, wide, prominent, well let down	2	....	....
Legs, straight, short; feet and pasterns strong	5	....	....
Body, 32 points:			
Chest, deep, broad; girth, large	7	....	....
Sides, deep, lengthy, and full	8	....	....
Back, broad, straight, thickly and evenly fleshed	7	....	....
Loin, thick, wide, and strong	5	....	....
Belly, straight, even, and firmly fleshed	3	....	....
Flank, low and well fleshed; girth large	2	....	....
Hind quarters, 20 points:			
Hips, wide apart, smooth	3	....	....
Rump, long, wide, evenly fleshed, smooth	4	....	....
Hams, firm, heavily fleshed, deep and wide	8	....	....
Legs, straight, short; feet and pasterns strong	5	....	....
Total	100	....	....

Remarks..

Name of scorer.............................. Date......................

SCORE CARD FOR UTILITY POULTRY.

Variety... Exhibit No. ......

Points.	Perfect.	Scorer's.	Corrected.
General appearance, 30 points:			
Weight, according to age	2	....	....
Form long, moderately deep, broad, low set, conforming to breed type, top line and under line straight	8	....	....
Condition, face and head appurtenances bright red, eye bright and full, feathers glossy, uniformly well fleshed throughout	6	....	....
Style, active and vigorous, not restless, showing strong character	7	....	....
Quality, bone moderately fine, feathers soft, skin and scales mellow, flesh fine texture, evenly distributed	7	....	....
Head and neck, 20 points:			
Head short, broad between the eyes, neither coarse nor snaky in appearance	5	....	....
Comb medium in size, bright in color, fine texture, and well attached	3	....	....
Beak short, stout, broad at the base, well curved	3	....	....
Eye clear and full	2	....	....
Face short, full, with a clean-cut appearance	2	....	....
Wattles and lobes medium in size, fine in texture and smooth	1	....	....
Neck moderate in length, well joined to head and shoulders	4	....	....
Body and legs, 50 points:			
Shoulders broad and rather flat on top	4	....	....
Back broad, fair length, width well carried back	6	....	....
Breast moderately deep and wide, full and round	10	....	....
Keel well forward, long and straight, well covered with flesh throughout	12	....	....
Tail well spread and full, no pinched effect	4	....	....
Thighs medium length, plump	6	....	....
Legs straight, fairly short, set well apart, strong but not coarse	8	....	....
Total	100	....	....

Remarks..

Name of scorer.............................. Date......................

SCORE CARD FOR MARKET EGGS.

Class.. Exhibit No. ......

Points.	Perfect.	Scorer's.	Corrected.
Shape: Uniformly oval, no ridges	10		
Color: Uniform over entire shell and throughout the dozen. Rich dark brown for brown, clear white for white	10		
Weight: For each ounce short of the grade standard cut one-half point	15		
Shell: Strong, not porous. Spotlessly clean and unsmeared or glossy by washing	15		
Quality: Fresh and sweet, full, clean viscous white, rich golden yolk that stands up	50		
Total	100		

Remarks..

Name of scorer.................................... Date....................

BUTTER SCORE CARD.

Breed of animal.................... Name.................... Register No......

Points.	Perfect.	Scorer's.	Corrected.	Defects.
Flavor	45			Metallic. Curdy. Fishy. Feverish. Oily. Weedy. Stable. Unclean. High acid. Low acid.
Texture	25			Poor grain. Weak body. Cloudy brine. Too much brine. Cheesy. Greasy. Tallowy.
Color	15			Mottles. White specks. Too high. Too light. Streaky.
Salt	10			Too much salt. Poor salt. Lacks salt. Gritty.
Condition of package	5			Dirty. Poorly packed. Poorly nailed. Poorly lined.
Total	100			

Remarks..

Name of scorer.................................... Date....................

SCORE CARD FOR WHITE BREAD.

Class of exhibit.................................. Exhibit No...............

Points.	Perfect.	Scorer's.	Corrected.
General appearance (20 points):			
Size	5		
Shape	5		
Crust { Color, Character, Depth }	10		
Flavor, odor, and taste	35		
Lightness	15		
Crumb (30 points):			
Texture { Fine—coarse, Tender—tough, Moist—dry, Elastic or not }	20		
Color	5		
Grain: Distribution of gas	5		
Total	100		

Remarks...
Name of scorer.................................... Date.....................

The above score is explained by Miss Isabel Bevier in University of Illinois Bulletin 25, Vol. X.

Ten points are awarded at the New York State College of Agriculture for a written report which must accompany the loaf telling (*a*) brand of flour and kind of yeast used, (*b*) how mixed and set to rise; number of times set to rise, (*c*) time of baking and about what temperature, (*d*) care after baking, (*e*) number and value of hours of labor consumed, total cost of loaf, and the approximate number of loaves that could be made in the time taken in making one.

The 10 points for report may be taken by omitting size and counting lightness as 10 only.

SCORE CARD FOR CANNED FRUIT OR VEGETABLES.

Kind........................ Variety...................... Exhibit No......

Points.	Perfect.	Scorer's.	Corrected.
Flavor: The flavor should be agreeable and as nearly as possible that of the fresh, perfect fruit or vegetable	45		
Texture: Well cooked—so that it is tender, yet not overcooked	25		
Condition: Liquid clear. No sign of decomposition. Product should be uniform in size, well arranged in can, and of good color	10		
Purity: Free from foreign material, preservatives, or artificial color	10		
Package: Cans should be uniform and of quality, shape, and size practicable to the average home. The labels should be suitable, uniform, and neat	10		
Total	100		

Remarks...
Name of scorer.................................... Date.....................

SCORE CARD FOR JELLY.

Kind.. Exhibit No......

Points.	Perfect.	Scorer's.	Corrected.
Color	10		
Transparency	20		
Taste, flavor, acidity, etc	25		
Consistency:			
Holds shape well, not flow	15		
Tender, will cut easily	15		
Firm angles, retain shape	5		
Freedom from crystallization	10		
Total	100		

Remarks..

Name of scorer.................................... Date..................

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 282

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER August 11, 1915

A STUDY OF THE SOFT RESINS IN SULPHURED AND UNSULPHURED HOPS IN COLD AND IN OPEN STORAGE.

By G. A. Russell,

Expert, Drug-Plant and Poisonous-Plant Investigations.

CONTENTS.

INTRODUCTION.

During the past decade the soft resins of hops have been the subject of numerous investigations which have dealt almost exclusively with the percentage of yield and the methods of extraction. With the exception of the work of Fischer,[1] no statements have been found in the literature to show that recognized chemical methods have been used to determine the changes which occur in the soft resins of hops subsequent to harvesting. The effect of refrigeration on the physical condition and on certain chemical constituents of sulphured and unsulphured hops has been studied by Stockberger and Rabak,[2] who gave special consideration to the changes which occur in the volatile oil. Aside from the changes noted by these authors, extensive modifications also occur in the soft resins of hops, the character of which may be determined through the use of reliable analytical methods.

[1] Fischer, Alfred. Analysis of hops as a basis for their valuation. *In* Pure Products, v. 8, no. 10, p. 536–538. 1912.

[2] Stockberger, W. W., and Rabak, Frank. Some effects of refrigeration on sulphured and unsulphured hops. U. S. Dept. Agr., Bur. Plant Indus. Bul. 271, 21 p. 1912.

NOTE.—This bulletin presents the results obtained from experiments conducted to determine the extent and character of the changes in the soft resins in hops under varying conditions of curing and storage. The soft resins, or so-called bitter acids, are a principal factor in determining the commercial value of hops.

98657°—Bull. 282—15——1

In order to obtain additional data regarding the effect of various storage conditions upon the soft resins of sulphured and unsulphured hops, a quantity of material was prepared and held under observation for several years. The data secured indicate that there is a marked chemical rearrangement or balancing of at least a part of the components of these resins during the first year after the hops are harvested. This rearrangement is most marked in hops kept in cold storage, and of these it is most evident in the unsulphured hops.

It is generally conceded that the commercial value of hops is almost entirely contingent upon two considerations, namely, the character of the aroma and the nature and quantity of the soft resins. At the last International Hop and Barley Exhibit, held in Chicago in 1911, the score card gave an equal rating to aroma and to the soft resins, or, as they are sometimes termed, the hop bitter acids.

Although sulphuring and cold storage are efficient factors in retarding the diminution of the quantity of soft resins in hops, they do not prevent chemical changes from taking place therein. Nevertheless, the data obtained by the study of these changes indicate that they are influenced to a considerable degree by both sulphuring and cold storage. The experiments detailed in the following pages were made with a view to determining the extent and character of these changes.

PREPARATION OF THE HOPS STUDIED.

Since soil and climate, as well as other factors, are undoubtedly responsible for the varying quantity of soft resins found in hops of different geographical origin, all the samples of hops used in this investigation were secured from a common source, in order to eliminate variation so far as possible. Accordingly, two lots of hops harvested from the same field at Perkins, Cal., in September, 1911, were dried in ordinary hop kilns, one portion without being sulphured, the other receiving the customary sulphuring in the early stages of drying. Duplicate samples of each lot were then placed in hermetically sealed tin cans and shipped to Washington, D. C. About the 1st of December one sample each of the sulphured and unsulphured hops was subjected to analysis, and the remaining samples, each weighing 2 kilograms, were then removed from the tins, compressed to about the same degree as the hops in a commercial bale, and completely inclosed in a cover of ordinary hop sacking. Three each of these sulphured and unsulphured samples were then placed in cold storage in the hop storeroom of a local brewery, and a similar set of samples was placed in the attic of a frame building at the Arlington Experiment Farm, Virginia. On December 1 of each of the three following years one sample each of the sulphured and the unsulphured hops was withdrawn from cold and open storage, respectively, and subjected to analysis.

CHANGES IN PHYSICAL APPEARANCE.

On receipt of the various samples of hops from Perkins, Cal., in 1911, they were examined and the following notes taken respecting their physical characteristics:

Sulphured hops in the original lot.—Fine fresh hop flavor; oily feeling; lupulin sticky; aroma excellent; color bright, characteristic of new fresh hops; color of lupulin bright.

Unsulphured hops in the original lot.—Fine fresh hop flavor; oily feeling; lupulin sticky; aroma excellent; color bright, characteristic of new fresh hops, though somewhat greener in appearance than the corresponding sulphured sample; color of lupulin bright.

On December 1 of the three following years, two samples each from cold and from open storage were examined and the following notes were taken on their physical characteristics:

Sulphured hops in cold storage one year.—Fresh hop flavor; oily feeling; lupulin sticky; aroma good; color darker than the original sample, not so bright and characteristic; color of lupulin bright.

Unsulphured hops in cold storage one year.—Fresh hop flavor; oily feeling; lupulin sticky; aroma good; color much darker than the original sample, not so bright and characteristic; color of lupulin bright.

Sulphured hops in open storage one year.—Strawlike flavor; oily feeling; lupulin less sticky; aroma disagreeable; color dull, bright color having disappeared; color of lupulin dull.

Unsulphured hops in open storage one year.—Strawlike flavor; oily feeling less noticeable; lupulin less sticky; aroma disagreeable; color very dull; color of lupulin dull.

Sulphured hops in cold storage two years.—Decided strawlike flavor; oily feeling very slight; lupulin slightly sticky; aroma slightly hoplike; color dark yellow, brightness having disappeared; color of lupulin dull.

Unsulphured hops in cold storage two years.—Most decided strawlike odor, somewhat musty; oily feeling practically gone; lupulin not sticky; aroma like musty straw; color dark brownish yellow; color of lupulin very dull.

Sulphured hops in open storage two years.—Decided strawlike flavor; oily feeling practically gone; lupulin slightly sticky; aroma that of musty straw; color dark brownish yellow; color of lupulin very dull.

Unsulphured hops in open storage two years.—Very decided musty flavor; oily feeling gone; lupulin very slightly sticky; aroma that of musty straw; color dark brownish yellow; color of lupulin very dark and dull.

Sulphured hops in cold storage three years.—Most decided strawlike flavor, somewhat musty; oily feeling gone; lupulin very slightly sticky; aroma that of old musty straw; color dark brownish yellow; color of lupulin very dark and dull; hop cones falling apart.

Unsulphured hops in cold storage three years.—Very decided musty, strawlike flavor; oily feeling entirely gone; lupulin not sticky; aroma that of old musty straw; color very dark, dirty brownish yellow; color of lupulin very dark and dull; hop cones falling apart.

Sulphured hops in open storage three years.—Very decided musty, strawlike flavor; oily feeling entirely gone; lupulin not sticky; aroma that of old musty straw; color dark brownish yellow; color of lupulin very dark and dull; hop cones fallen apart.

Unsulphured hops in open storage three years.—Most decided musty, strawlike flavor; oily feeling entirely gone; lupulin not sticky; aroma that of old musty straw; color very dark brownish yellow; color of lupulin very dark and dull; hop cones fallen apart.

As far as physical valuation indicates, the sulphured hops in cold storage deteriorated at a slower rate than the unsulphured hops, and the same is true for the samples placed in open storage. At the end of one year of storage very little physical difference could be noticed in the cold-storage hops other than that the color had darkened in both the sulphured and unsulphured samples, more especially in the latter. The samples in open storage at the end of one year had each developed a strawlike odor and had become dull in color. The lupulin of both the sulphured and unsulphured hops had begun to lose its brightness and its sticky feeling.

At the end of the second year of storage a most decided change had taken place in all the samples. The sulphured hops in cold storage had developed a strawlike flavor and a dry feeling and the bright color had disappeared. The unsulphured samples had developed a musty odor and an extremely dry feeling, and the characteristic greenish yellow color had disappeared. The unsulphured hops had deteriorated more rapidly than the corresponding sulphured hops. So far as the physical valuation indicated, the hops in open storage had deteriorated to a much greater degree than the hops in cold storage. The unsulphured samples in open storage had become very musty in odor and very dark in color, in addition to losing their crisp and sticky feeling.

At the close of three years of storage the samples had lost all traces of hop flavor and had developed a musty, strawlike odor. A slight stickiness could still be detected in the sulphured hops in cold storage. The hop cones in the cold-storage samples had fallen apart to some extent, whereas those in the open storage samples had completely fallen apart. The lupulin in all the samples was much discolored.

MOISTURE CONTENT AND CHANGES IN THE PROPORTION OF SOFT AND HARD RESINS.

At the time the hops were received in Washington a sample each of the sulphured and unsulphured hops was analyzed and the results thus obtained were used as the basis for comparing the analyses which were made of the various samples during each year of storage.

MOISTURE CONTENT.

For the determination of the moisture content 12 grams of hops were taken from each of the samples under investigation, dried over sulphuric acid until of constant weight, and the loss in weight returned as moisture. The moisture content of the original hops and of the hops in both cold and open storage for the several years is given in Table I.

TABLE I.—*Moisture in the original samples of sulphured and unsulphured hops and in samples kept in cold and in open storage.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.			Open storage.		
		1912	1913	1914	1912	1913	1914
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sulphured	6.18	11.04	11.04	9.83	5.81	6.37	6.40
Unsulphured	5.23	10.90	10.79	10.90	6.14	5.90	5.50

From Table I it is evident that the moisture content of the hops kept in cold storage was greater than of those in open storage. In the samples kept in cold storage the moisture content was very uniform for the three years in both the sulphured and the unsulphured hops, indicating that the cold-storage room was kept at a uniform temperature throughout this period. In the open-storage samples a slight fluctuation in the moisture content was evident, due apparently to differences in the atmospheric conditions at the time the samples were removed for analysis. Since moisture is an important adjunct to a great many chemical changes, it is probable that the greater quantity found in the samples kept in cold storage had a direct bearing on the chemical changes that took place in the soft resins.

SOFT RESINS.

In determining the quantity of soft resins in the hop samples, a departure was made from the method usually employed. A kilogram of hops was extracted by maceration and percolation with petroleum ether (B. P. 35° C. to 70° C.). Two macerations were necessary to complete the extraction. The mixed percolates were then heated on a water bath at 70° C. and the major portion of the petroleum ether recovered. The remainder of the petroleum ether was allowed to evaporate spontaneously and the weight of the residue returned as soft resins. The residues each contained a small fraction of approximately 0.4 per cent of wax, which for purposes of comparison may be disregarded. The percentage of soft resins in the original sulphured and unsulphured samples and in the corresponding samples in cold and in open storage is shown in Table II.

TABLE II.—*Soft resins in the original samples of sulphured and unsulphured hops and in samples kept in cold and in open storage.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.			Open storage.		
		1912	1913	1914	1912	1913	1914
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sulphured	12.32	11.91	11.46	4.98	11.32	9.03	3.20
Unsulphured	11.17	9.72	8.66	3.81	8.73	7.43	2.32

Regarding, first, the sulphured hops, the data in Table II show that the percentage of soft resins decreased somewhat during the first and second years of storage and very rapidly during the third year. The decrease was less, however, in the cold-storage samples than in those kept in open storage. The unsulphured hops show a marked decrease from year to year, the decrease being most pronounced in the third year of storage. The unsulphured samples in open storage show a greater loss than the corresponding samples kept in cold storage. During the first year of open storage the soft-resin content in the sulphured hops decreased less rapidly than in the unsulphured hops, but more rapidly in the following two years.

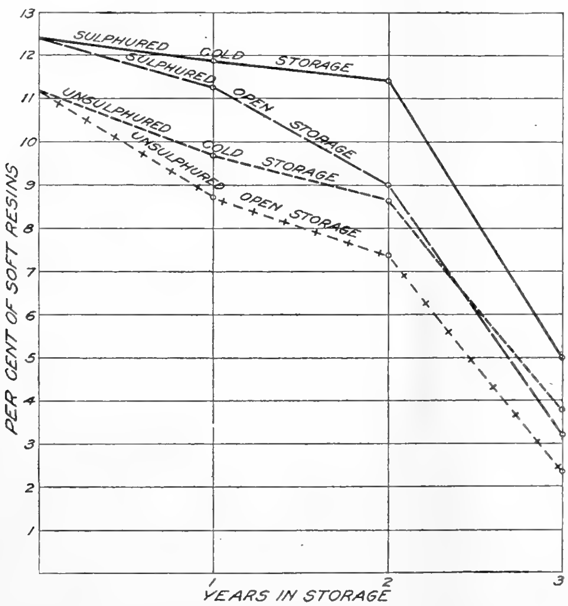

FIG. 1.—Curves of the percentage of soft resins in sulphured and unsulphured hops in cold and in open storage.

It will be observed from figure 1 that the quantity of soft resins present in the sulphured hops in both cold and open storage decreased during each year and that the decrease was especially marked during the third year of storage. Figure 1 also shows that the unsulphured hops in cold storage decreased in soft-resin content more rapidly than the sulphured hops and that this decrease was rapid during the first year, less pronounced during the second year, and at the end of the third year gradually approached the same point of value as in the sulphured hops in cold storage. The soft-resin content of the unsulphured hops in open storage decreased at about the same rate as that of the sulphured hops in open storage.

The percentage of decrease in soft resins during the three years, as compared with the original samples, is given in Table III.

TABLE III.—*Decrease in the soft resins of sulphured and unsulphured hops in cold and in open storage compared with the soft-resin content of the original samples.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.			Open storage.		
		1912	1913	1914	1912	1913	1914
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sulphured	100	3.32	6.98	59.57	8.11	26.71	74.02
Unsulphured	100	12.98	22.47	65.89	21.84	33.48	79.23

From Table III, in which the soft-resin content in the original samples is considered as 100 per cent, it is evident that the decrease in the sulphured hops during the first two years in cold storage was not great, but it was rapid during the third year. In open storage the decrease was very pronounced during each year. The unsulphured hops in cold storage show a marked decrease, which was greatest in the third year, and in open storage the decrease was even more pronounced year by year.

HARD RESINS.

The hard resins in the various samples of hops used in this study were also determined. A portion of the hops after being extracted with petroleum ether was again extracted with ether, the ether recovered, and the weight of the residue returned as hard resin. By this method an extra calculation is necessary, but in using large quantities of hops the time consumed is more than compensated for in the accuracy obtained.

The hard-resin content of the various samples is shown in Table IV.

TABLE IV.—*Hard resins in the original samples of sulphured and unsulphured hops and in samples kept in cold and in open storage.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.			Open storage.		
		1912	1913	1914	1912	1913	1914
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sulphured	5.26	6.53	8.97	9.90	8.32	9.09	10.10
Unsulphured	6.43	8.35	10.08	10.05	9.53	10.45	10.46

The figures in Table IV give an index of the change in the quantity of hard resins that took place in the various hop samples. The greatest change occurred in the unsulphured hops in open storage and the least change in the unsulphured hops during the first two years in cold storage. The difference in the content of hard resins of both sulphured and unsulphured hops in cold and in open storage, respectively, became materially less in the third year of storage and probably indicates that the changes which took place in the hops tended to reach a state of equilibrium irrespective of the treatment of the sample.

Figure 2 gives a graphic representation of the increase in the hard-resin content of sulphured and unsulphured hops in cold and in open storage.

During the first year the increase in the hard-resin content in the sulphured hops was greater in open storage than in cold storage. At the end of the second year the sulphured hops in both cold and open storage contained about the same percentage of hard resins. The unsulphured hops followed the same lines, but did not present quite so marked a difference during the first year of storage. At the end of the third year the hard-resin content in all the samples had become uniform and a state was reached where the increase, if any, was very slow.

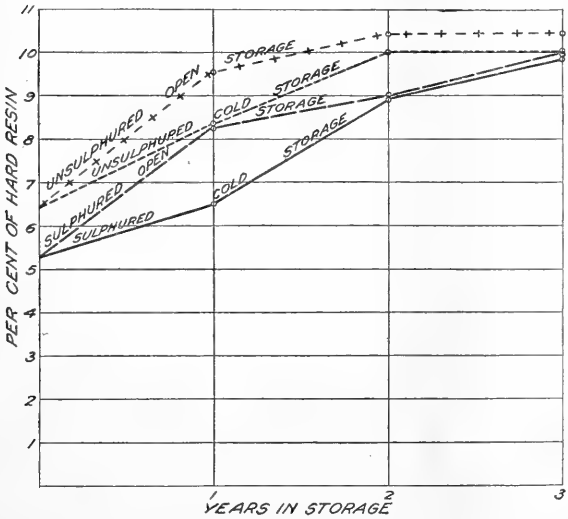

FIG. 2.—Curves of the percentage of hard resins in sulphured and unsulphured hops in cold and in open storage.

Table V gives the percentage of increase in the hard-resin content of the various samples as compared with the original, the hard-resin content of the latter being considered as 100 per cent.

TABLE V.—*Increase in the hard resins of sulphured and unsulphured hops in cold and in open storage, compared with the hard-resin content of the original samples.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.			Open storage.		
		1912	1913	1914	1912	1913	1914
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sulphured	100	24.14	70.53	88.21	58.17	72.81	92.01
Unsulphured	100	29.85	52.75	56.29	48.21	62.51	62.67

The sulphured hops appeared to react less readily to changes that bring about an increase in the hard resins. From this it is inferred that sulphuring is a factor that retards the changing of soft resins to hard resins. This is shown most emphatically in Table V by the fact that the percentage of increase in the unsulphured hops was much less in both cold and open storage than in the corresponding sulphured hops. A further study of Table V indicates that a combination of sulphuring and cold storage was most effective in retarding the changes that produce hard resins.

TOTAL RESINS.

The total resin content of the various hop samples, found by adding the soft resins and the hard resins together, is shown in Table VI.

TABLE VI.—*Total resins in the original samples of sulphured and unsulphured hops and in samples kept in cold and in open storage.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.			Open storage.		
		1912	1913	1914	1912	1913	1914
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sulphured	17.58	18.44	20.43	14.88	19.64	18.12	13.30
Unsulphured	17.60	18.07	18.74	13.86	18.26	17.88	12.78

From the figures in Table VI it appears that some discrepancies exist, since the total resins in some years ran higher than those of the original sample. Experiments in this laboratory have shown that two samples are rarely ever the same in total yield of resins; hence, no weight need be attached to the apparent discrepancies.

The sudden decrease in the total resins in all the samples in the year 1914 is of special interest. Up to this point the hops in storage had retained approximately their original content of soft resins. A marked diminution now occurred in the content of soft resins, which is not compensated by a corresponding increase in the content of hard resins. It appears from the data at hand that a portion of the soft resins had been transformed into a compound or compounds insoluble in ether or in petroleum ether, since the marked loss in percentage of soft resins does not appear in the ether extract. The extent of the change was greatest in the unsulphured hops in open storage and least in the sulphured hops in cold storage, but in all samples, irrespective of treatment either at the kiln or during storage, the decrease was rapid. Table IV shows that at the end of the second year of storage a point was reached by all the samples beyond which the hard resins did not materially increase. Nevertheless, at this point the soft resins began to decrease most rapidly. Although previous investigators have stated that the soft resins change entirely to hard resins, it is probable that only a small portion of the soft resins undergoes such a change, and the remainder is changed into a compound or compounds insoluble in the solvents used in extraction and for that reason is lost sight of in the analysis.

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TABLE VII.—*Soft resins in the original samples of sulphured and unsulphured hops and in samples kept in cold and in open storage, calculated with reference to the total resins.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.			Open storage.		
		1912	1913	1914	1912	1913	1914
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sulphured	70.13	64.59	56.08	33.47	57.63	49.83	24.06
Unsulphured	63.46	53.79	46.21	27.49	47.80	41.55	18.15

The data in Table VII show that the sulphured cold-storage hops retained a greater percentage of soft resins each year than did any of the other samples. The unsulphured hops in cold storage and the sulphured hops in open storage contained year by year practically the same percentage of soft resins, as calculated with reference to the total resins. The greatest decrease is noted in the soft resins from the unsulphured hops in open storage.

CHANGES IN THE COMPOSITION OF THE SOFT RESINS.

That chemical changes take place in the soft resins of hops is a foregone conclusion. In order to study these changes, methods in general use in chemistry, with some modifications, were applied to the soft resins with satisfactory results. The physical properties of color and odor presented in Table VIII were observed from year to year.

TABLE VIII.—*Physical properties of the soft resins in the original samples of sulphured and unsulphured hops and in samples kept in cold and in open storage.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.		
		1912	1913	1914
Color:				
Sulphured	Greenish brown.	Dark brown	Greenish brown.	Greenish black.
Unsulphured	Dark brown	Very dark brown.	do	Do.
Odor:				
Sulphured	Aromatic, pleasant.	Aromatic, pleasant.	Aromatic, pleasant.	Aromatic, unpleasant.
Unsulphured	do	Aromatic, pungent.	Agreeable, hoplike.	Do.

Treatment at the kiln.	Original sample, 1911.	Open storage.		
		1912	1913	1914
Color:				
Sulphured	Greenish brown.	Dark brown	Greenish brown.	Greenish black.
Unsulphured	Dark brown	do	do	Do.
Odor:				
Sulphured	Aromatic, pleasant.	Aromatic, pleasant.	Aromatic, pleasant.	Disagreeable, somewhat aromatic.
Unsulphured	do	Aromatic, pungent.	Aromatic, pungent.	Do.

All the samples had an extremely bitter taste, manifested strongly at the base of the tongue when a minute particle of the soft resin was held in the mouth for a few seconds.

The color, odor, and taste, which appeal solely to the senses, are of relatively small importance in this investigation. As shown in Table VIII, the color of the soft resins in all cases became darker with the age of the sample examined; the odor became very disagreeable with the decrease of the soft resins and the taste at all times remained very bitter.

The soft resins are fluid in nature, and during the first two years of storage all were of the same consistency. Those extracted in 1914 were more solid and had the consistency of a thick sirup. Owing to their nature, the specific gravity of these resins could not be determined with accuracy.

ACID AND ESTER VALUES.

The determination of the free acidity or acid value of the soft resins was carried out as follows: A small quantity of weighed soft resin was taken up in 2 c. c. of standardized alcoholic potassium hydroxid and the excess potassium hydroxid titrated back with N/10 hydrochloric acid. The acid value represents the number of milligrams of potassium hydroxid necessary to completely neutralize the free acids in 1 gram of the soft resins.

In determining the ester value of the soft resins a weighed portion was taken up in standardized alcoholic potassium hydroxid and allowed to stand 24 hours in the cold. Complete saponification took place in that length of time. The excess alkali was titrated back with N/10 hydrochloric acid and the saponification value calculated. This value, minus the acid value, gives the ester value of the soft resins and represents the number of milligrams of potassium hydroxid necessary to completely saponify all the combined acids in 1 gram of the soft resins. The changes observed in the acid and ester values are shown in Table IX.

TABLE IX.—*Acid and ester values of the soft resins in the original samples of sulphured and unsulphured hops and in samples kept in cold and in open storage.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.			Open storage.		
		1912	1913	1914	1912	1913	1914
Acid value:							
Sulphured	71.80	97.00	87.50	80.7	72.5	61.50	47.0
Unsulphured	60.87	67.00	76.50	76.2	52.0	70.00	77.6
Ester value:							
Sulphured	97.7	169.5	191.1	226.3	122.5	202.5	271.0
Unsulphured	121.78	71.5	87.0	207.8	123.5	158.0	158.4

A graphic representation of the acid values is given in figure 3. From this figure it will be seen that after the first year of storage the acid value of the soft resins diminished in the sulphured hops and gradually increased in the unsulphured hops. The rise in acid value of the soft resins of the sulphured hops during the first year in cold storage was probably due to the rearrangement that was taking place in these resins; although esters were formed during this period the esterification did not proceed as rapidly as in the following years, with a consequent rise in free-acid value. During the first year of open storage the acid value of the soft resins of the sulphured hops remained about the same and then gradually decreased at a rate proportionate to that of the sulphured hops in cold storage. The formation of esters was slow during the first year of storage and rapid during the next two years, reaching a slightly higher value at the end of the third year than in the corresponding sample in cold storage.

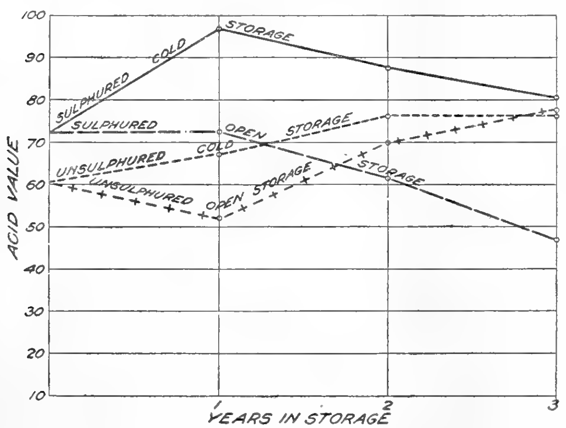

FIG. 3.—Acid-value curves of the soft resins in sulphured and unsulphured hops in cold and in open storage.

The unsulphured hops in cold storage yielded soft resins whose acid value constantly increased throughout the period of storage. The ester value for these soft resins decreased during the first year, then gradually increased during the second year, and very rapidly during the third year of storage. In open storage the acid value in the unsulphured hops was slightly less at the end of the first year than in the corresponding original sample. The ester value (fig. 4) remained almost constant, indicating that there was little change in these values during the first year of storage. From this point the acid values from the unsulphured hops increased gradually, until at the end of the third year of storage about the same degree of acidity was reached.

The increase in acidity was, however, most marked in the unsulphured hops in open storage. The ester values for the soft resins of the unsulphured hops increased after the first year of storage and was most rapid in the cold-storage samples.

The acid value of the soft resins from sulphured hops in both cold and open storage gradually diminished at approximately the same rate after one year of storage. The corresponding ester values increased in approximately the same proportion as the acid values diminished. This decrease in the acid value and increase in ester value would indicate that esterification took place faster than free acids were formed, the original quantity of free acids being practically used up. In other words, the sulphuring of hops appears to hasten the formation of esters in the soft resins but retards the formation of free acids.

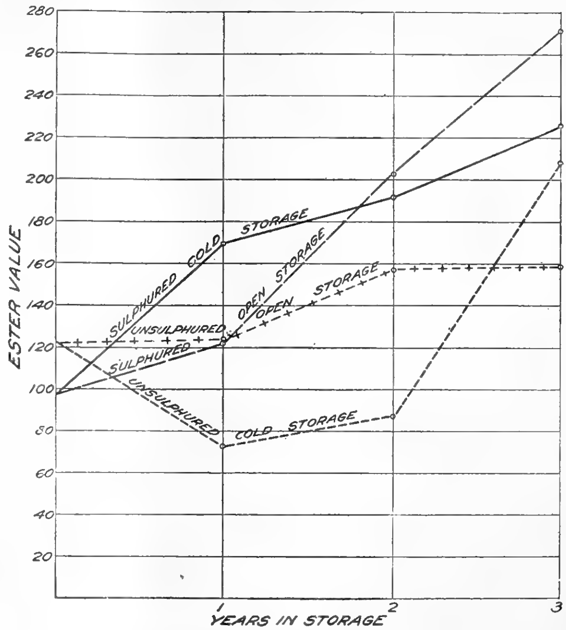

FIG. 4.—Ester-value curves of the soft resins in sulphured and unsulphured hops in cold and in open storage.

The acid value of the soft resins from the sulphured hops in both cold and open storage gradually increased during the period of storage, and the corresponding ester value likewise gradually increased, indicating that in the unsulphured hops the formation of free acids and of the corresponding esters goes on with regularity.

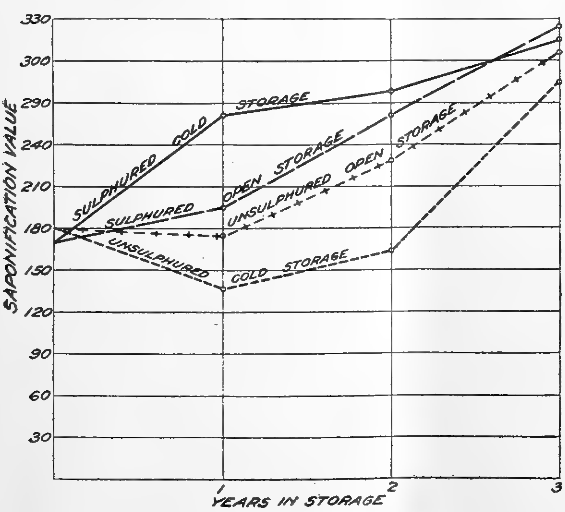

FIG. 5.—Saponification-value curves of the soft resins in sulphured and unsulphured hops in cold and in open storage.

SAPONIFICATION VALUE.

The saponification value, shown in Table X and indicated graphically in figure 5, was in this study determined before the ester value, although it is usually obtained by adding the acid and ester values of the product under investigation. From a study of the ester and acid values, a gradual increase in the saponification value would be expected. This increase was most marked after the first year of storage, and all the samples gradually approached a uniform value. The saponification value of the soft resins from the sulphured hops was slightly higher than the same value in the unsulphured hops. The increase in the saponification value was most uniform in the hops held in open storage and was most rapid during the third year in the unsulphured hops in cold storage.

TABLE X.—*Saponification value of the soft resins in the original samples of sulphured and unsulphured hops and in samples kept in cold and in open storage.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.			Open storage.		
		1912	1913	1914	1912	1913	1914
Sulphured	169.5	266.5	278.5	317	195	264	324
Unsulphured	182.65	138.5	163.5	284	175.5	228.5	236

IODIN VALUE.

In determining the iodin-absorption value of the soft resins, the method employed was that commonly used in determining this value in fats. The results obtained are shown in Table XI.

TABLE XI.—*Iodin value of the soft resins in the original samples of sulphured and unsulphured hops and in samples kept in cold and in open storage.*

Treatment at the kiln.	Original sample, 1911.	Cold storage.			Open storage.		
		1912	1913	1914	1912	1913	1914
Sulphured	95	76	144	156	123	132	156
Unsulphured	100	72	140	141	89	143	153

The iodin values, as shown in Table XI and in figure 6, became less divergent in the third year of storage. In the soft resins from the sulphured hops in open storage the iodin value gradually increased for each year of storage. In all the other samples it diminished during the first year, rose rapidly during the second year, and in the third year was uniform with that from the sulphured hops in open storage. This indicates a diminution in the unsaturated compounds in the soft resins from the sulphured hops in cold storage and from the unsulphured hops in both cold and open storage and an increase in the unsaturated compounds in sulphured hops in open storage during the first year. It will be noted, however, that after the completion of the marked readjustment that took place during the first year of storage, the iodin value of all the samples tended to become uniform, thus indicating that the unsaturated compounds were present in approximately the same proportion in all the soft resins of all the hop samples at some point between the first and the second year of storage.

CHEMICAL VALUES OF THE SOFT RESINS.

In order to make more apparent the correlation between the various chemical values found in the soft resins from year to year, these values have been brought together and are represented graphically in figures 7, 8, 9, and 10.

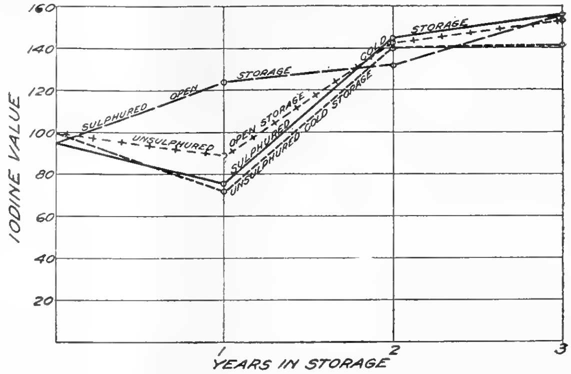

FIG. 6.—Iodin-value curves of the soft resins in sulphured and unsulphured hops in cold and in open storage.

Figure 7 shows the various values as found in the sulphured hops in cold storage. The acid value, which increased during the first year of storage, gradually decreased during the second and third years. The ester value, which increased very rapidly during the first year of storage, diminished somewhat during the next two years. Figure 7 shows also that although esterification took place rapidly during the first year of storage it could not keep pace with the formation of free acids; thus the latter increased. During the remainder of the time the hops were in storage esterification continued, but the quantity of free acids formed was not so great, with the result that there was a decrease in free acidity.

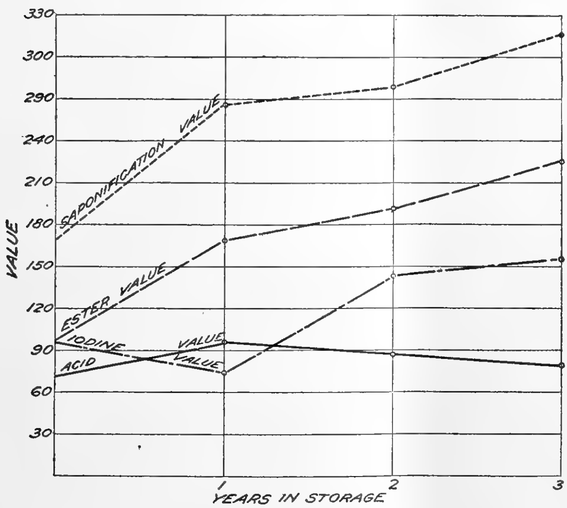

FIG. 7.—Curves showing the correlation of chemical values of the soft resins in sulphured hops in cold storage.

The saponification value gradually increased throughout the storage period. The iodin value at the end of the first year of storage was less than that of the original sample, indicating that the formation of unsaturated compounds in the soft resins had been retarded in the sample held in storage. The iodin value increased during the second year, indicating a greater production of unsaturated compounds in the soft resins.

Figure 8 shows the various values as found in the sulphured hops in open storage. The acid value, which remained almost constant during the first year of storage, gradually diminished during the next two years. The ester value, which increased somewhat during the first year, increased rapidly during the second and third years, indicating that the esterification was slightly in advance of the formation of free acids at all periods of storage and became more pronounced at the close of the third year. The iodin value gradually increased, indicating the continuous formation of unsaturated compounds in the soft resins throughout the entire period of storage. The saponification value gradually increased throughout the period of storage.

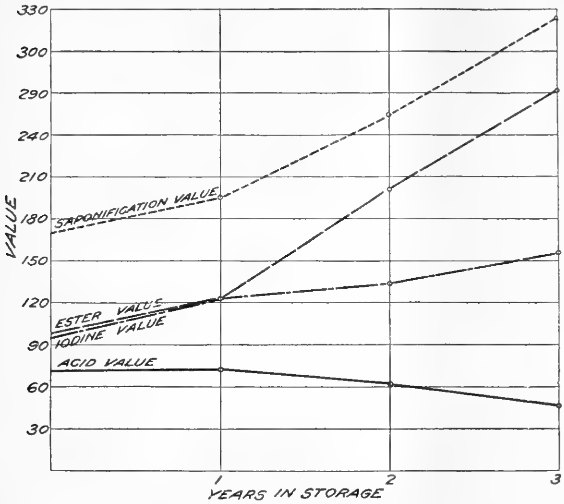

FIG. 8.—Curves showing the correlation of chemical values of the soft resins in sulphured hops in open storage.

Figure 9 gives a graphic illustration of the various values as found in the unsulphured hops in cold storage. The acid value gradually increased throughout the period of storage. The ester value diminished during the first year of storage, increased somewhat during the second year, and in the third year the increase was rapid. Figure 9 shows also that esterification did not keep pace with the formation of free acids during the first year of storage. However, during the next

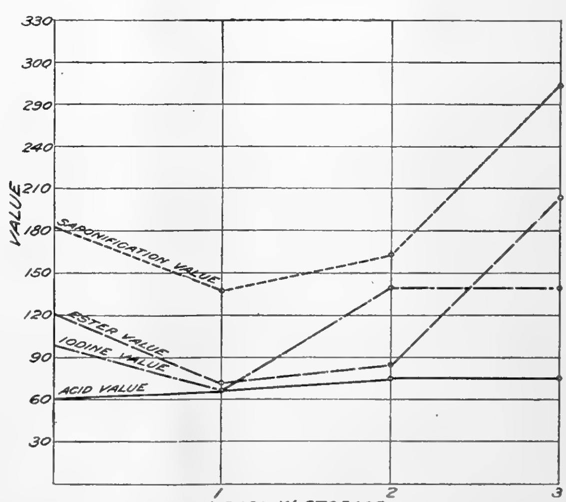

FIG. 9.—Curves showing the correlation of chemical values of the soft resins in unsulphured hops in cold storage.

two years it was more rapid, with a consequent increase in the ester value.

The saponification value gradually increased after the first year of storage. The iodin value likewise increased after the first year, although during that year it diminished somewhat, but during the second year it increased rapidly, indicating thereby that the unsaturated compounds formed in the soft resins also increased rapidly, and they remained fairly constant after this point was reached until the close of the third year.

Figure 10 shows the various values as found in the unsulphured hops in open storage. The acid value diminished slightly during the first year and increased each year thereafter. The ester value increased slightly during the first year, quite rapidly during the second year, and remained constant during the third year, esterification in this sample practically keeping pace with the formation of free acids throughout the storage period. The saponification value, which decreased slightly during the first year of storage, increased during the second and third years. The iodin value decreased slightly during the first year, increased rapidly during the second year, and slightly during the third year, indicating thereby that the unsaturated compounds in the soft resins remained fairly constant during the first year, increased rapidly during the second year, and were fairly constant during the third year of storage.

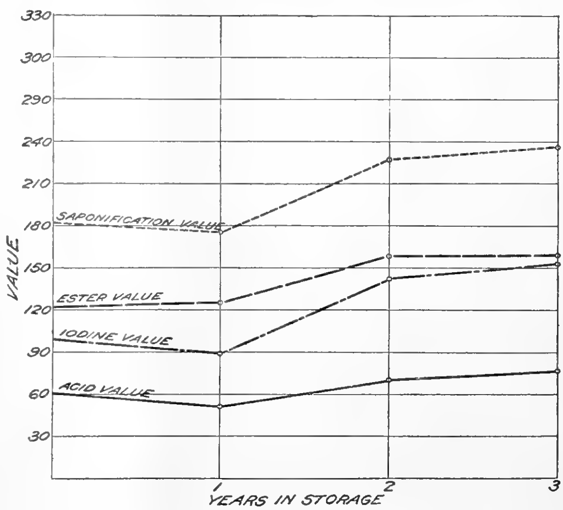

FIG. 10.—Curves showing the correlation of chemical values of the soft resins in unsulphured hops in open storage.

The relations of these various values may be briefly summarized as follows:

(1) A change took place in some of the components of the soft resins of the hops, indicative of a marked rearrangement in these compounds during the period that elapsed between picking the hops and the end of one year of storage.

(2) This change was most pronounced in the hops in cold storage, irrespective of treatment at the dry kiln. However, on comparison, the unsulphured hops showed the greatest change.

(3) This change was not so pronounced in the hops kept in open storage, irrespective of treatment at the dry kiln. On comparison, however, the unsulphured hops showed the greatest change.

(4) The most decided change occurred in the unsulphured hops in cold storage and the least marked change in the sulphured hops in open storage.

(5) After the first year the degree of change in all the samples fluctuated with regularity from year to year. Taken in the aggregate, the values as determined from year to year indicate most strongly that an extensive rearrangement took place in the soft resins of the hops from the time they were picked until some point was reached between the first and second year of storage. When this point was reached and the rearrangement had practically terminated, a gradual increase or decrease could be traced in all the values taken.

SUMMARY.

In 1911, material for a comparative study of the soft resins of sulphured and unsulphured hops in both cold and open storage was secured from a hop ranch at Perkins, Cal. The green hops were divided into two lots, one of which was sulphured during the process of drying. The dry sulphured and unsulphured hops were again divided into lots, sealed in tin cans, and shipped to Washington, D. C. On arrival the cans were opened and an analysis made of one lot each of the sulphured and unsulphured hops. The remaining samples were baled in burlap and three samples each of the sulphured and unsulphured hops were placed in both cold and open storage.

At the end of the first, second, and third years of storage one sample each of the sulphured and unsulphured hops was withdrawn from both cold and open storage and an analysis made of each. The hops analyzed in 1911 are designated as "original hops," since they approximate more nearly the condition of the samples at the time of drying.

A physical valuation was placed on the original samples and also on the hops as they were withdrawn from storage from time to time. From these valuations the conclusions are drawn that both sulphuring and cold storage retard changes in the physical characteristics of hops. A combination of the two factors is more effective in retarding these changes than either factor alone.

Determinations were made of the moisture, the percentage of soft resins, hard resins, and total resins, of the color, odor, and taste of the soft resins, and of the acid, ester, saponification, and iodin values of the soft resins.

The moisture content in the sulphured and unsulphured hops held in cold storage increased during the first year and then remained practically constant in all the samples throughout the period of storage. The moisture content of the sulphured and unsulphured hops in open storage varied from year to year, according to existing weather conditions.

The percentage of soft resins in all the samples decreased with each year of storage, becoming very pronounced in the third year. The percentage of hard resins in all the samples increased with each year of storage, approaching a uniform figure at the close of the third year. Both sulphuring and cold storage retarded the decrease in the percentage of soft resins and increased the percentage of hard resins. A combination of the two factors was more effective in retarding these changes than either factor alone.

The percentage of total resins in all the samples varied from year to year, and in the third year it became materially less than that of the original sample. The low total is probably due to the formation of products insoluble in the solvents used.

The color, odor, and taste of the soft resins are of very little value in determining quality and are not indicative of any changes that may have taken place therein.

The acid value in general decreased in the sulphured hops in cold and in open storage and increased in the unsulphured hops in cold and in open storage. Sulphuring apparently retards the formation of free acids, and a combination of sulphuring and cold storage is most effective in retarding changes in free acidity.

The ester value in general increased in all the samples of hops. Sulphuring apparently favors the formation of esters, and this factor in combination with open storage appears to be the least effective in retarding the formation of esters. Nonsulphuring and open storage appear to be the most effective in retarding the formation of esters.

The saponification value in general increased in all the samples of hops. The unsulphured hops showed the least change, and of these the ones held in open storage were the least affected.

The iodin value in general increased in all the samples. It was most pronounced in the second year of storage and in the third year was uniform in all the samples. Sulphuring in combination with open storage appears to cause a uniform rate of increase in the iodin value from year to year. The sulphured hops in open storage showed the least variation in changes in the chemical values of the soft resins.

During the period of storage, at least some of the components of the soft resins underwent rearrangement. This rearrangement was most marked during the first year, after which it decreased to such an extent that thereafter comparable values for the chemical constants were readily obtained.

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MILTON WHITNEY, Chief

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CONTENTS.

THE PRODUCTION OF SULPHURIC ACID AND A PROPOSED NEW METHOD OF MANUFACTURE.

By WILLIAM H. WAGGAMAN, *Scientist in Fertilizer Investigations.*

INTRODUCTION.

The importance of sulphuric acid in science, arts, and manufacture has been increasing steadily for many years. Although scarcely any industry exists which does not employ this acid either directly or indirectly in the manufacture of its product,[1] the bulk of the sulphuric acid produced, both in this country and abroad, is used in the manufacture of fertilizer materials.

Since Liebig first proposed the treatment of bones or phosphate rock with sulphuric acid in order to render the phosphoric acid present water soluble, superphosphate has been the basis of the fertilizer industry, and the economic production of sulphuric acid has been the aim of numerous investigators and chemical engineers. The production of sulphuric acid of various strengths in the United States for the past three years, according to the figures of the United States Geological Survey, is given in Table I.

Because of the difficulty in shipping such a commodity all of the sulphuric acid produced is consumed in this country. Some of the products manufactured therefrom are shipped abroad but the quantity of acid entering into them is but a small percentage of the total production.

In 1913 the United States consumed 1,931,468 short tons of phosphate rock. Since practically all of this was made into acid phos-

[1] Phalen, W. C. Mineral Resources (1913).

phate, at least 2,000,000 tons or over 56 per cent of the total sulphuric acid produced was thus consumed. A large tonnage of acid is also consumed annually in the manufacture of ammonium sulphate, a by-product of the coking and gas industries, and also in the production of what are known to the fertilizer trade as "base goods," consisting of acidulated hair, wool, tankage, or other nitrogenous refuse of the packing industry.

TABLE I.—*Production of sulphuric acid in the United States for the years 1911, 1912, 1913, by grades.*

Year and grades.	Quantity.	Value.	Price per ton.
	Tons.	*Dollars.*	*Dollars.*
1911:			
50° Baumé	1,026,896	5,447,958	5.31
60° Baumé	421,165	2,624,042	6.23
66° Baumé	751,541	9,176,297	12.21
Other grades	10,728	121,575	11.33
Total and average	2,210,330	17,369,872	7.86
Total reduced to 50° Baumé	[1] 2,688,456	[1] 17,313,822	6.44
1912:			
50° Baumé	1,047,483	5,378,411	5.13
60° Baumé	451,172	2,727,764	6.05
66° Baumé	774,772	9,360,630	12.08
Other grades	66,166	871,214	13.17
Total and average	2,339,593	18,338,019	7.84
Total reduced to 50° Baumé	[2] 2,876,000	[2] 17,572,837	6.11
1913:			
50° Baumé	1,643,318	9,212,917	5.61
60° Baumé	509,929	3,202,528	6.28
66° Baumé	797,104	9,282,422	11.65
Other grades	63,158	986,659	15.62
Total and average	3,013,509	22,684,526	7.53
Total reduced to 50° Baumé	[3] 3,538,980	[3] 22,366,482	6.32

[1] Exclusive of acids of strength greater than 66° Baumé.
[2] Exclusive of electrolyte and acids of strength greater than 66° Baumé.
[3] Exclusive of 22,947 short tons of fuming acid, not convertible, valued at $318,044.

METHODS OF MANUFACTURE.

There are two general methods employed in the manufacture of sulphuric acid, namely the "contact process" and the "lead-chamber method." It is not within the scope of this paper to discuss in detail the numerous modifications of these two methods, but classified lists of the patents on the subject, together with short abstracts thereof, are given at the end of this paper.

THE CONTACT PROCESS.

Briefly the contact process consists in passing a purified mixture of air and sulphur dioxide derived either from sulphur or burning pyrites over some catalytic agent heated to dull redness, thereby effecting the further oxidation of the sulphur dioxide. The resulting sulphur trioxide is then usually absorbed in sulphuric acid, producing a very concentrated product.

Theoretically this should prove the simplest, cheapest, and most efficient method of making sulphuric acid, but in actual practice there are several details encountered both in the construction and running of a plant which unless given careful consideration will seriously affect the yield of acid and the cost of production.

Many different catalytic agents have been tried (notably platinum, palladium, iridium, the oxides or sulphates of iron, copper, chromium manganese, and silver, as well as the oxides of some of the rarer elements) in effecting the oxidation of sulphur dioxide, but no matter what catalyzer is used its efficiency is seriously impaired and often destroyed unless very elaborate systems are employed for purifying the gases before admitting them into the oxidation chamber. For instance, finely divided platinum (platinum black) has proved the most efficient catalyzer so far discovered, but the catalytic power of this body in bringing about the union of sulphur dioxide and air is seriously affected by the smallest traces of arsenic in the gaseous mixture. When pyrites are used as a source of sulphur dioxide, the arsenic which this mineral nearly always contains, passes over with the furnace gases and it is only by repeated washing and filtering that the last traces of this element can be removed.

Contrary to general opinion, therefore, a contact plant is both elaborate and costly and strict supervision by a competent chemical engineer is necessary to insure the best results.

The contact process has distinct advantages over the lead-chamber method where a pure concentrated acid is required, but in the manufacture of ordinary sulphuric acid (50° to 60° B.) for the fertilizer industry or for other purposes where the purity of the product is not essential, the latter method still holds first place (at least in this country) for efficiency and low cost of production.

THE LEAD-CHAMBER PROCESS.

The lead-chamber process with its various modifications has been fully treated by Lunge.[1] This author, as well as numerous other investigators, notably Weber, Winkler, Rascheg, Meyer, Pratt, Gilchrist, Falding, and Wedge, has described details of construction, methods of accelerating the chamber reactions, and proposed and discussed schemes for increasing the efficiency and lowering the cost of acid systems. It is thought, however, that a brief general description of the chamber process will help toward a better understanding of the modification of the process proposed in this paper.

In this country nearly all of the sulphuric acid is made from pyrites. The lump ore is imported chiefly from Spain, while the "fines" are a domestic product mined in Virginia, Georgia, Tennessee, and California. If the lump ore is used it is burned in brick

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[1] Treatise on the Manufacture of Sulphuric Acid and Alkali, vol. 1.

furnaces having grates composed of single square bars which can be turned on their longitudinal axes to let the cinders down into the ash pits. Such furnaces hold from 3 to 5 tons each and are arranged in batteries of 20 to 25 for each set of lead chambers. The daily charge for each furnace when the system is in operation is from 750 to 1,000 pounds of pyrites. The burners for the pyrites "fines" consist of cylindrical furnaces having a series of shelves so arranged that the burning material can be mechanically raked from shelf to shelf until the fully burned cinder is discharged at the bottom of the furnace. The rakes are attached to a central air or water cooled shaft. In one type of furnace the shaft revolves; in another the shaft is rigid while the furnace itself revolves.

The gases from the pyrites burners are forced into a dust chamber fitted with baffle plates where the oxides of iron, arsenic, lead, zinc, etc., are in a large measure removed. From the dust chamber the gases enter the Glover tower, which consists of a lead tower (usually from 20 to 30 feet high and 6 to 8 feet across) lined with acid-resisting brick and partly filled with quartz or other acid-proof material so arranged that the dilute nitrous vitriol which is distributed from an apparatus at the top of the tower will trickle down through the interstices. The heat of the burner gases which enter the Glover tower at a temperature of from 300° to 400° C. drives off water and the oxides of nitrogen from the nitrous vitriol, restoring them to the system. The uses of the Glover tower therefore are threefold: first, to cool the furnace gases before allowing them to enter the lead chambers; second, to restore water and the oxides of nitrogen to the system; and third, to produce an acid more concentrated than that formed in the lead chambers.

From the Glover tower the gases enter the first of the lead chambers where most of the sulphuric acid is made. The lead chambers usually consist of large square or oblong boxes[1] made of sheet lead (weighing from 6 to 8 pounds per square foot) and having a capacity of from 25,000 to 75,000 cubic feet. Water in the form of fine spray or steam is introduced into the chambers at various points. This decomposes the nitrosulphuric acid formed into sulphuric acid and returns the oxides of nitrogen to the system to be again acted upon by the furnace gases. The number and size of the chambers used vary from 2 to 10 or more, depending on the number and size of the pyrites burners. Where the quantity of sulphur burned daily is large the acid plant is often divided into separate units, each battery of burners furnishing gases to its own set of lead chambers. The gases pass from the first to the second chamber and so on through

[1] In the Meyer Tangent system the lead chambers are cylindrical in form, while in the Falding system their height is several times their length and width.

the system, sulphuric acid being formed till the sulphur dioxide is practically exhausted.

The residual gases, consisting of nitrogen, oxides of nitrogen, some oxygen, and a small percentage of sulphur dioxide, then enter the lower part of the Gay-Lussac or recovery tower, which is similar in construction to the Glover tower, except that it is usually taller and wider (from 40 to 50 feet high and 8 to 15 feet across) and filled with coke instead of quartz. Strong sulphuric acid (1.5 to 1.7 specific gravity) trickles down the tower, absorbing the oxides of nitrogen from the residual gases which ascend through the coke column, and are finally discharged through a stack. The nitrous vitriol formed is then pumped to the Glover tower, diluted with water, and distributed as previously described.

MEASUREMENT OF A PLANT'S EFFICIENCY.

The efficiency of a lead-chamber plant is measured, first, by the amount of chamber space required for each pound of sulphur burned in 24 hours and the amount of acid (50° or 60° B.) made therefrom, and, second, by the amount of niter consumed or lost in the production of this acid.

Practically all sulphuric acid authorities agree that, provided the gases are present in the proper proportions, the two most important conditions necessary for efficient production are a thorough mixing of the gases and the control of their temperature.

The importance of the first of these conditions is self-evident, since in order to bring about complete chemical reaction the reacting substances must be in intimate contact with one another. The second condition is important because too low a temperature lessens the chemical activity of the gases, while a temperature above 100° C. prevents the condensation of water which it is claimed is necessary to bring about the decomposition of nitrosulphuric acid, an intermediate compound formed from the oxides of nitrogen in the system.

Numerous schemes to control these conditions have been devised, some of which have features of considerable interest and practical importance. While it is impracticable in a paper of this length to discuss in detail all of these processes, several that have been tried, apparently with some success, are described below.

METHODS FOR ACCELERATING THE CHAMBER REACTIONS.

Walter and Boeing [1] advocate the use of several hollow acid-proof partitions built across the chambers and so arranged that the gases enter the compartments through large holes near the bottom and are discharged from holes near the top. Numerous other small holes

[1] German patent No. 71908.

allow the admission and exit of the gases, thereby causing them to mix intimately without seriously interfering with the draft.

Because of the doubtful stability of these inner walls and the serious damage caused on their collapse this method is no longer used.

Gossage [1] as well as several other investigators proposed filling the chambers with coke so that the gases would be obliged to work their way through the interstices and thereby become thoroughly mixed. This scheme, however, has been abandoned because of the impurities introduced into the acid by the coke and the tendency of the coke columns to press against the lead walls, causing them to bulge and even break. The lack of any cooling device in this process also caused excessively high temperatures in the chambers.

Verstrart's [2] plan is similar to the above, except that stacks of bottomless stoneware jars filled with coke are used. The oxides of nitrogen are supplied to the system by allowing nitric acid to trickle down one of the stacks.

In Pratt's [3] process, which is much used in the Southern States, the gases are drawn through the first chamber by means of a fan, then through a tower packed with quartz down which flows dilute sulphuric acid, and finally they are reinjected into the front of the first chamber by means of the same fan. This circulatory system seems quite efficient and a number of plants where the process is employed are operating on less than 9 cubic feet of chamber space per pound of sulphur burned in 24 hours.

Meyer's [4] tangental chambers are designed both to mix and to cool the reacting gases at the same time.

The chambers are cylindrical in form, the first having water-cooled lead pipes suspended around the circumference. The gases are admitted at a tangent near the upper part of the chamber walls and are discharged from outlets in the centers of the chambers' bottoms. The gases are thus given a spiral motion which tends to mix them thoroughly while the water-cooled lead pipes reduce their temperature.

There are three installations of this type of plant in the United States. One at least is reported to have given great satisfaction.

Hartmann [5] obtained an increased yield of acid in the lead-chamber process by placing vertical, air-cooled lead pipes in the chambers. The chamber bottom is turned up around the lower ends of these pipes, forming hydraulic seals, and thus obviating the necessity of joints in the bottom of the chamber.

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[1] Lunge, Treatise on Manufacture of Sulphuric Acid, 1 Pt. I, p. 475.
[2] Bull. Soc. encour. ind. nat., 1865, p. 531.
[3] U. S. patents Nos. 546, 596, 652, 687.
[4] English patent No. 18376: Zeit. für ang. Chem. (1900), p. 742.
[5] Chem. Zeit., 1897, p. 877.

Blau [1] proposed to cool the gases in the first chamber by injecting a spray of cold sulphuric acid, and in order to obtain the optimum yield of acid from the gases in the subsequent chamber their temperature is raised by injecting sprays of warm sulphuric acid.

Falding's process [2] has for its object the segregating of the active gases in a system. To accomplish this he employs a chamber the height of which is approximately one and one-half times greater than its horizontal dimensions. The burned gases after passing through the Glover tower in the usual way are introduced either near the top or lower down on the chamber's side. Since the fresh gases are hot, not only because they have recently issued from the pyrites burners but because of the reactions taking place between some of the constituents, they collect in the upper part of the chamber in a relatively active layer.

As the reactions subside the spent gases gradually cool and settle to the bottom of the chamber, where they are withdrawn. Falding claims that by using the high chamber a zone of great chemical activity is always maintained in the upper part of the chamber, and that the spent or inactive gases, which in ordinary chamber systems act as diluents, are continually being removed from the active zone. It is also claimed that much less chamber space is required to complete the reactions by this process, so that even where large volumes of gases are handled each chamber is a unit in itself, being connected directly with the Glover tower instead of in series as in ordinary chamber systems.

A number of plants in this country are equipped with chambers of this type and it is reported that the process is commercially successful.

The main objections to the Falding system, in the opinion of the writer, are, first, that no provision is made for obtaining an intimate mixture of the gases other than the preliminary mixing brought about in the Glover tower, and, second, that no adequate means is provided for the condensation of the acid mist formed by the reactions.

The most widely used method of mixing and cooling the reacting gases is by means of intermediate towers containing plates, tubes, or baffles of some acid-resisting material cooled either by water, air, or dilute sulphuric acid. A number of different types of towers have been designed, but mention is here made of only a few of the better-known designs.

Lunge's plate tower [3] consists of a shell of lead either cylindrical or angular in form and filled with a series of perforated plates laid

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[1] German patent No. 95083.
[2] U. S. patent 932771 (1909).
[3] Treatise on Sulphuric Acid, vol. 1, Pt. I, pp. 478-498.

horizontally. Each layer of plates is supported at some distance above the other by bearers in such a way that every plate is independent of the others. The plates are so constructed and placed that the holes in those of one layer do not come directly above the holes in the next layer below.

Dilute sulphuric acid is allowed to trickle down the tower, splashing from one layer of plates to another and meeting the hot-chamber gases as they wind upward through the tower. The film of dilute acid over the plates presents an immense cooling surface to the gases and at the same time furnishes the water necessary for the decomposition of the nitrosulphuric acid. The formation of this latter compound is, according to Lunge, a necessary link in the chamber process.

Gilchrist's pipe-column system [1] consists of lead towers (3 or 4 feet across and 15 feet high) having corrugated lead tubes, open at both ends, running through them horizontally like a steam boiler. The sides of the towers are boxed in with boards so as to form an air shaft which terminates in a flue at the top.

The chamber gases, together with water vapor, enter the pipe columns at the sides near the bottom and work their way upward through the towers. Contact with the air-cooled corrugated tubes condenses the sulphuric acid, which then drips in showers from one series of pipes to another and frees the oxides of nitrogen, restoring them to the system. The gases issue from the top of the towers and enter the next chamber, from which they are drawn into another series of pipe columns, and so on through the system till their oxidation is practically complete.

While some of the methods just described are designed to cut down the amount of chamber space required, none of them, with the exception of Falding's process, reduces the initial cost of erecting an acid plant; for, while less lead may be employed in constructing the chambers, the expense of the cooling and mixing towers more than offsets the saving in chamber material.

Another objection to most of the accelerating devices discussed above is that in order to mix the gases thoroughly they must be drawn or forced through small openings or made to pursue a meandering course by means of baffles or some acid-proof packing material in the towers. Under such conditions dust or impurities may clog the apparatus, choking off the draft and making it necessary to clean out the tower or chamber before operations can be resumed. Moreover, the collapse or disarrangement of the packing material within the tower may cause even more serious trouble.

Nearly all modifications of the chamber process complicate somewhat the running of an acid plant, and should therefore be constantly under the supervision of a competent chemical engineer.

[1] Jour. Soc. Chem. Ind., 18, 459–462 (1899).

In the new modification of the chamber method described in this publication a complete mixture of the gases and the control of their temperature is brought about without the use of expensive or complicated apparatus and with practically no danger of clogging the system. While this method has been tried out only in the laboratory, and some of the analytical data are not altogether satisfactory, the results obtained prove that the principle is good and that the process, if worked on a factory scale, would probably be commercially successful.

In a review of the patent literature on the subject an apparatus was found which is somewhat similar to the one herein described. This United States patent (No. 446060) was taken out by E. and J. Delplace in 1891 and consists of a lead chamber having the shape of a ring with a sector cut out. The chamber is provided with two gas inlets at unequal distances from the center and contains at intervals distributing pipes leading from the upper part to the lower part of the chamber, so that the hot gases can be more thoroughly mixed with the cooler. The inventors state that in such a chamber the constant change in the direction of the gases and their impinging on the sides of the chamber cause a thorough mixture and a condensation of the acid formed. In this patent the right is reserved to vary the shape of the chamber provided the gases are led through a circular route.

The main objections to the above apparatus, in the opinion of the writer, are, first, that the chamber as described is of such a size that there must be spaces therein where the gases are relatively inactive; second, the pipes for conveying the hotter gases from the upper to the lower part of the chamber would hardly accomplish this unless they were the only route provided for the passage of the gases, and this according to the specifications is not the case; third, the use of pipes within the lead chamber unless they are cooled is always objectionable because of their excessive corrosion and the serious consequences resulting therefrom; fourth, a chamber of the shape described occupies an enormous amount of ground space. Where land values are high, this entails a large outlay for a factory site, as well as an expensive building to house the chamber.

NEW MODIFICATION OF THE CHAMBER PROCESS.[1]

This method is based on the fact that if a mixture of warm gases is drawn downward through a special flue their resistance to the downward pull, together with the constant change of their course, will tend to mix them very intimately, and unless the internal diameter of the flue is too great there will be practically no zones of inac-

[1] Work carried on under the direction of Dr. F. K. Cameron, to whom the author is indebted for much valuable assistance.

tivity in the apparatus. Moreover, the constant impinging of the gases on the walls of the spiral flue, which can be cooled either by air or water, makes it practicable to maintain the gases at a temperature most favorable for the efficient yield of sulphuric acid.

In the following laboratory experiments, however, the sulphur dioxide (SO_2) used was not directly derived from burning pyrites or sulphur, so it was necessary to heat the system artificially to attain a temperature as high as that obtained under factory conditions.

The sulphur dioxide was obtained from a small cylinder of the liquefied gas, which was weighed both before and after each experiment, and the SO_2 used thus determined. The oxides of nitrogen (chiefly N_2O_3 and N_2O_4) were produced by the action of dilute nitric acid on copper, and the rate at which they were used was roughly

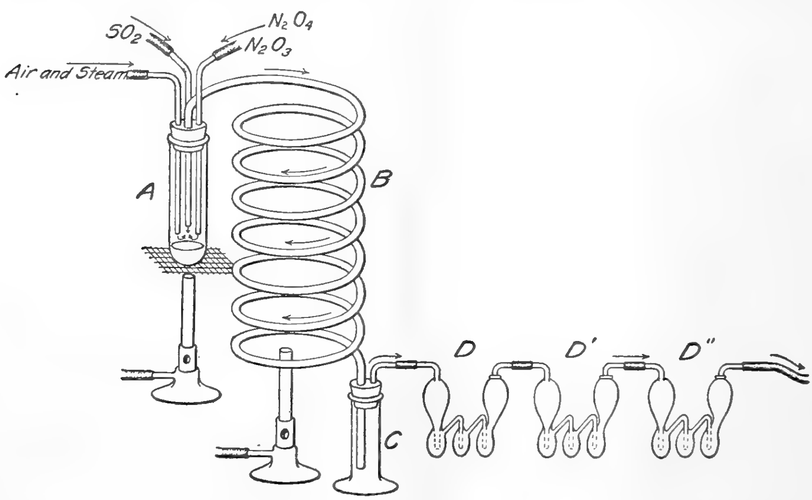

FIG. 1.—Apparatus used in proposed new method for manufacture of sulphuric acid.

determined by allowing the gases to bubble through dilute sulphuric acid saturated with these gases. A mixture of air and water vapor was obtained by drawing air through a flask of water heated to the boiling point.

The apparatus employed (fig. 1) consisted, first, of a large test tube (A), having a capacity of 200 c.c., and containing a little water heated to boiling. The oxides of nitrogen, sulphur dioxide, air, and water vapor were led to the bottom of this vessel by separate tubes and given a preliminary mixing. From the test tube the gases were drawn into the lead or glass spiral (B), which was heated to about 90° C. in order to facilitate the reactions. In winding downward through this spiral the warm gases were thoroughly mixed, with the result that most of the sulphuric acid produced in the system was formed in this coil. The residual gases were then passed through the absorption bulbs (D, D′, D″) containing strong nitric acid, which absorbed the sulphur dioxide escaping oxidation in the spiral.

The quantities of sulphur dioxide converted into sulphuric acid in the tube (A) and the spiral (B), as well as that which escaped oxidation and was subsequently absorbed in the bulbs (D, D′, D″), were determined by analyses. The results of these analyses are given in Tables II and III.

When the lead spiral was used (Table II), the amount of sulphuric acid formed therein had to be determined by difference because of the formation of lead sulphate, which could not be entirely removed from the tube by washing.

On account of the many joints and rubber connections necessary in the apparatus there was some loss of sulphur dioxide in the system. When the lead spiral was used, the amount of this loss could not be determined, so all the errors occurring in Table II are thrown into column 5, making the figures for the sulphur dioxide oxidized in the lead spiral larger than they actually should be.

TABLE II.—*Sulphur dioxide oxidized to sulphuric acid in apparatus shown in figure 1. Lead spiral used and steady stream of oxides of nitrogen furnished throughout experiments.*

Number of run.	Time of run.	Rate per hour of SO_2.	SO_2 oxidized in system.		SO_2 lost in system.[1]	SO_2 escaping from end of spiral.
			In vessel A.	In lead spiral B.		
	Hours.	*Grams.*	*Per cent.*	*Per cent.*		*Per cent.*
5	2	6.2017	32.07	67.92	....	0.01
7	2	6.4887	26.61	73.39	....	Trace.
8	2	7.6569	23.00	76.99	....	.01

[1] Could not be determined. Included in the figures in column 5.

An inspection of Table II shows that by passing sulphur dioxide, air, and water vapor through a lead spiral in the presence of an adequate supply of the oxides of nitrogen, the formation of sulphuric acid is practically complete, even when the gases are run at quite a rapid rate.

In ordinary chamber plants it is considered very good practice if only 10 feet of chamber space is required for every pound of sulphur burned in 24 hours. Figuring the chamber space required in run No. 8, it is seen that for every pound of sulphur burned in 24 hours only 0.139 foot of chamber space was required.

While it is hardly fair to compare the results obtained in the laboratory with those obtained on a factory scale, still the efficiency of the apparatus can be more readily judged by expressing the results in the conventional way.

The well-known characteristic of some metals, as well as metallic oxides and salts, of acting as catalytic agents made it seem possible that the lead, lead oxide, or lead sulphate had something to do with the very efficient yield of acid obtained when using the lead spiral. Accordingly, a glass coil of the same length and internal diameter was substituted in the experiments shown in Table III.

TABLE III.—*Sulphur dioxide oxidized to sulphuric acid in apparatus shown in figure 1. Glass spiral used and steady stream of oxides of nitrogen furnished.*

Number of run.	Time of run.	Rate per hour of SO_2.	SO_2 oxidized in system.		SO_2 lost in system.	SO_2 escaping from end of spiral.
			In vessel A.	In glass spiral B.		
	Hours.	*Grams.*	*Per cent.*	*Per cent.*		*Per cent.*
20	1½	3.8311	14.17	75.14	3.15	7.34
19	1½	4.6404	43.99	50.18	3.20	2.63
12	2	5.7888	20.18	71.66	1.26	6.28

Table III shows that the yield of acid was not so great with a glass as it was with a lead spiral. In no instance was the gas run through the apparatus so fast as in the experiments in Table II, yet even though the oxides of nitrogen were present in large quantities in the gaseous mixture there was a loss of sulphur dioxide from the end of the spiral.

In order to try out the catalytic action of the lead coil, several runs were made with both the glass and lead spirals, but using no oxides of nitrogen. The results of these experiments are shown in Tables IV and V.

TABLE IV.—*Sulphur dioxide oxidized to sulphuric acid in apparatus shown in figure 1. Lead spiral used, but no oxides of nitrogen employed.*

Number of run.	Time of run.	Rate per hour of SO_2.	SO_2 oxidized in system.		SO_2 lost in system.[1]	SO_2 escaping from end of spiral.
			In vessel A.	In spiral B.		
	Hours.	*Grams.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
21	1	3.2642	0.40	38.08	....	61.52
16	1	3.8459	.41	40.78	....	58.81

[1] Could not be determined. Included in figures in column 5.

TABLE V.—*Sulphur dioxide oxidized to sulphuric acid in apparatus shown in figure 1. Glass spiral used, but no oxides of nitrogen employed.*

Number of run.	Time of run.	Rate per hour of SO_2.	SO_2 oxidized in system.		SO_2 lost in system.	SO_2 escaping from end of spiral.
			In vessel A.	In spiral B.		
	Hours.	*Grams.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18	10	2.6713	(1)	0.75	[2] 10.02	89.23
15	10	2.8393	0.40	0.68	[2] 12.36	86.56

[1] Included in next column.
[2] The large loss of sulphur dioxide in the system was due in part to the renewal of the sulphuric acid in the wash bottle through which the gas was allowed to bubble before entering the system. This acid was not entirely saturated with SO_2 before these experiments were undertaken.

In comparing the results obtained in Tables IV and V it is evident that the lead spiral had some influence in the oxidization of the sulphur dioxide to sulphuric acid. The figures in column 5, Table IV, are obviously too high since all the errors due to the loss of gas in the system are thrown into this column. But while the sulphur dioxide and air was in each instance run through the lead spiral at greater speed than through the glass coil, the quantity escaping oxidation was much less in the former than in the latter case.

In order to determine if the catalytic action observed in the lead coil was due to lead or lead sulphate, two experiments were conducted using the glass spiral but no oxides of nitrogen. The conditions in these experiments were approximately the same as in those recorded in Table V except that in the first run the interior of the glass coil was coated with precipitated lead sulphate and in the second a lead chain was introduced into the glass spiral. The results are shown in Table VI.

TABLE VI.—*Sulphur dioxide oxidized to sulphuric acid in glass spiral coated with lead sulphate and in the same spiral after the introduction of a lead chain.*

Number of run.	Time of run.	Coil used.	Rate per hour of SO_2.	SO_2 oxidized in system.		SO_2 lost in system.	SO_2 escaping from end of spiral.
				In vessel A.	In spiral B.		
	Hours.		*Grams.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
22	1.0	(1)	2.6594	0.25	9.80	(2)	89.95
23	1.0	(3)	1.7523	0.09	53.60	(2)	46.31
24	1.5	(1)	2.5299	0.05	17.85	(2)	82.10

[1] Glass coil coated with lead sulphate. [2] Not determined. [3] Glass coil containing lead chain.

Here again, as in Tables II and IV, the amount of sulphur dioxide lost in the system could not be determined, but the results shown in Table VI indicate that while lead sulphate has some influence on the oxidation of sulphur dioxide, lead or lead oxide is a much more energetic catalytic agent. The presence of the oxides of nitrogen in the system, however, is necessary for the complete oxidation of sulphur dioxide to sulphuric acid.

FACTORY CONSIDERATIONS.

In the construction of a sulphuric acid plant along the lines of the apparatus described in this paper, it is proposed to dispense with the lead chambers and intermediate towers only. The lead spiral is not intended to replace the Glover tower, which is so important in the preliminary mixing and cooling of the furnace gases and in restoring the oxides of nitrogen to the system, nor is it intended to do away with the Gay-Lussac tower, which is essential for the recovery of these same oxides of nitrogen from the residual gases.

The amount of lead required per cubic foot of chamber space is considerably greater for a long spiral tube as herein suggested than for a cylindrical chamber in which the height and diameter are more nearly equal, but the great reduction in the chamber space required to produce sulphuric acid in the spiral should make it possible to build a plant with considerably less lead than is required in an ordinary chamber system. Moreover, the facts that the new type of plant requires no other device to accelerate the reactions and occupies much less ground space than the present type of factory, and therefore would not need large buildings, should decrease the initial cost of construction.

The cooling of the lead spiral would be accomplished largely by the air, but if necessary in hot weather streams of water could be played upon its upper portion. The water thus warmed by the heat of the reaction of the upper part of the spiral would tend to raise the temperature of the lower portion of the spiral where the reactions are not so vigorous. The immense amount of cooling surface contained in such a spiral, together with the constant movement of the acting gases, should also prevent excessive corrosion of the lead walls.

While it is not fair, and hardly practicable, to predict how efficient a plant built along the lines of the apparatus just described would prove, all the indications are that such a scheme, worked on a factory scale, would be economically successful.

In the following tables the author has attempted to classify all the American patents on the manufacture of sulphuric acid, both by the contact and chamber processes. While these classifications are by no means drawn along sharp and distinct lines, still they should be of considerable assistance in enabling one to pick out the particular phase of acid manufacture which interests him most.

In tabulating and abstracting these patents it is probable that numerous important points have been omitted, but in many cases this was unavoidable because of the limited space available in tables of this character. It is thought, however, that the information given will enable those interested in the subject to judge fairly well whether or not any particular patent is of sufficient value to him to warrant further investigation.

NOTE.—Application has been made for a patent covering the process here described; if patent is allowed, it will be donated to the people of the United States.

APPENDIX.

TABLE VII.—*Apparatus and processes designed primarily for the efficient oxidation of SO_2 used in the manufacture of sulphuric acid by the "contact process."*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
636,924	1899	Schroeder, Max	Salt impregnated with platinum.	Process (no illustrations)	A mixture of platinum chloride and some other soluble salt is dissolved in water, the solution evaporated to dryness, and the platinum precipitated through the mass by heating.	Production of an efficient contact mass.
664,630	1900	Frasch, H. A.	Ferric oxide and iron compound, dried air, and SO_2.	Process (1 illustration. A converter).	A ferric-oxide producing substance is burned in a converter on a ferric-oxide base. Thoroughly dried air and SO_2 are passed over the material which is constantly being renewed from above.	Maintenance of fresh contact substance.
681,698	1901	Hasenbach, W.	Ferric oxide, dried air, and SO_2.	Process (no illustration)	Dried air is passed through burning pyrites and then the mixture of gases is led over burned pyrites.	Utilization of heat of burner gases and employment of cinder as catalyzer.
686,021	1901	Blackmore, H. S.	Oxide of iron, S, and SO_2	Not described. Process (no illustrations).	SO_2 impregnated with S vapor is passed over pyrites cinders. SO_3 absorbed in usual way.	Production of SO_3 and FeS.
686,022	1901	do.	Oxide of iron (supplementary to above).	Process (no illustrations)	SO_2 is passed over oxide of iron, reducing the latter. The oxide of iron is then regenerated by passing air over it.	Continual regeneration of contact substance.
687,834	1901	DeHaen, C. J. E.	Vanadic acid	do.	Mixture of air and SO_2 is passed over asbestos impregnated with vanadic acid.	Production of an efficient contact body.
690,133	1901	Clemm & Hasenbach.	Pyrites cinder and platinized asbestos, SO_2, and air.	Apparatus (2 illustrations) consisting of two contact chambers.	Mixture of gases is first passed over pyrites cinders, then dry filtered and passed over platinized asbestos.	Economy in filtering devices and less need of cooling devices.
700,512	1902	Krauss & Von Berneck.	Pyrites cinders impregnated with ferrous sulphate, SO_2, air.	Process (2 illustrations. Inclined rotating cylinder).	Pyrites cinders impregnated with ferrous sulphate are fed into the upper end of a rotating cylinder, meeting a current of air and SO_2 from the furnaces.	In hottest or lowest part of cylinder catalysis occurs, in next or middle zone $FeSO_4$ is decomposed evolving SO_3, and in the third or coolest zone SO_2 is fixed and returned to the system.
711,186	1902	Stone, G. C.	Separate compartments containing catalyzer, SO_2, air.	Apparatus (2 illustrations) consisting of a series of compartments containing the catalytic agent. Compartments can be renewed and replaced.	Gaseous mixture is passed through several chambers each of which contains some of the catalytic agent.	An efficient apparatus for renewing the contact body.

TABLE VII.—*Apparatus and processes designed primarily for the efficient oxidation of SO_2 used in the manufacture of sulphuric acid by the "contact process"*—Continued.

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
716,985	1902	Clemm, A.	Clay impregnated with copper sulphate, SO_2, air.	Process (no illustrations)	A mixture of SO_2 and air is led over unburnt clay impregnated with crystallized $CuSO_4$.	Efficient catalytic agent.
729,735	1903	Clemm & Hasenbach	Oxides of copper and chromium, platinum black, SO_2, air.	do	Gaseous mixture is first passed over oxides of copper and chromium, then through some porous medium to filter out impurities, and finally over platinized asbestos.	Efficient method of making SO_3 and H_2SO_4.
752,165	1904	Hasenbach, W.	Platinized fabric, SO_2, air.	Apparatus (4 illustrations). Chamber fitted at intervals with sheets of platinized asbestos.	A mixture of air and SO_2 is passed through a number of sheets of platinized fabric.	More efficient oxidation of SO_2, due to intimate contact of the gases with the catalyzer.
758,844	1904	Lunge & Pollitt	Pyrites cinders impregnated with arsenic, SO_2, air.	Process (no illustrations)	A mixture of air and SO_2 is passed up through pyrites cinder, the lower part of the column being rich in arsenic.	More efficient catalyzer.
769,585	1904	Blackmore, H. S.	Refrigeration, gold plated copper gauze, electric current, SO_2, air.	Apparatus (6 illustrations) consisting of chamber fitted with gold-plated wire gauzes, electrically heated.	A refrigerated mixture of air and SO_2 is passed up through a series of gold-plated copper gauzes heated by an electric current.	Apparatus which obviates the necessity of a catalytic agent and prevents dissociation of SO_3 formed.
774,083	1904	Knietsch, R.	Platinized asbestos on horizontal perforated plates, SO_2, air.	Apparatus (4 illustrations). A tube containing a series of perforated plates on which platinized asbestos is spread.	The gaseous mixture is passed up through the tube fitted at intervals with horizontal perforated plates, on which is spread platinized asbestos.	A more efficient method of exposing the gases to the catalyzer.
778,099	1904	Blackmore, H. S.	Refrigeration, CO_2, SO_2, heat.	Process (6 illustrations). Chamber fitted with gold-plated wire gauzes electrically heated.	A mixture of CO_2 and SO_2 is passed through a series of electrically heated gauzes. The SO_2 is oxidized as follows $SO_2+CO_2=SO_3+CO$. The endothermic reaction CO_2 to CO more than counteracts the heat of the reaction SO_2 to SO_3.	Control of temperature and obviation of the necessity of catalytic agent.
823,472	1906	Knietsch, R.	Platinized asbestos	Apparatus (4 illustrations) for conducting process described in patent No. 774,083.	Apparatus for patent No. 774,083	An apparatus for the efficient oxidation of SO_2 to SO_3.
869,094	1907	Kitsee, I.	Static electric discharges, SO_2, air.	Apparatus (1 illustration) consisting of a chamber in which the gases are led through electrical discharges.	The gases are led upward through a chamber and subjected to the action of electrical discharges.	Efficient method of oxidizing SO_2.

930,471	1909	Hallock, W	Radioactive or some other ionizing agent, SO_2, air, water.	Apparatus (1 illustration). Flask containing rod coated with radioactive material.	A mixture of air, SO_2, and water vapor is passed through the flask.	Oxidation of SO_2 to H_2SO_4.
988,646	1911	McFetridge, J	Finely divided oxide of iron, SO_2, air.	Apparatus (2 illustrations). Rotating furnace for burning pyrites and oxidizing part of SO_2, formed. A chamber plant then used to oxidize remainder of SO_2.	Finely divided pyrites are blown into a rotating furnace. The SO_2 formed is partially oxidized by the pyrites cinders. The dust is settled out of the gases and the SO_3 absorbed. The residual gases are then treated by the "chamber process."	Utilization of pyrites to oxidize (partially) the SO_2 formed.
1,007,5	911	Beckman, J. W	Alundum, particles, 40 pounds; copper oxide, 9 pounds; silica, 0.7 pound.	Process (no illustrations)	The ingredients are heated to a temperature slightly above the melting point of copper, and the latter then reduced in films over the alundum grains.	Production of an efficient porous catalytic agent.
1,018,402	1912	Albert, Kurt	A combination of ferric peroxide with an alkaline earth FeO_2. SrO, SO_2, air.	do	Sulphur dioxide and air are passed over the compound at a temperature of from 450° to 550° C.	Production of a contact body of great efficiency not so sensitive to moisture as pyrites cinders.
1,030,508	1912	Eschellmann & Harmuth.	A number of layers of platinized asbestos, SO_2, air.	Apparatus (3 illustrations). A contact chamber readily accessible for cleaning purposes containing numerous layers of platinized asbestos.	The mixture of SO_2 and air is passed first through a rather thick layer of platinized asbestos, then through a perforated plate, and finally through 25 layers of platinized asbestos.	An efficient contact chamber designed to mix and oxidize.
1,036,610	1912	Grosvenor, W. M	Catalyzer contained in several compartments of rotating cylinder, SO_2, air.	Apparatus (4 illustrations). A revolving cylinder containing the catalytic agent in several compartments.	The gaseous mixture is admitted into the apparatus in such a way that the cool gases come into contact with the hottest part of the catalyzer.	An efficient oxidation chamber.
1,102,670	1914	von Keler & Weinder	Silver vanadium compound	Process (no illustrations)	A compound of silver and vanadium.	Production of an efficient catalytic agent.
1,103,017	1914	Ellis, C	Tellurium or selenium compounds.	do	The substance is distributed through pumice or some other suitable porous medium.	Do.
1,103,522	1914	Lihme, I. P	Metallic oxide capable of absorbing hydrogen compounds of arsenic, SO_2, air.	Process (3 illustrations)	The gases are first passed over metallic iron to reduce the arsenic and then over pyrites cinders to absorb the arsenic hydride.	An efficient means of removing arsenic from burner gases.

TABLE VIII.—*Apparatus and processes designed to control the temperature of the gases used in the manufacture of sulphuric acid by the contact process.*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
652,119	1900	Knietsch, R.	Contact body, heat and refrigeration, SO_2, air.	Process (11 illustrations)	The gaseous mixture is heated by the reactions taking place in the contact chamber. The catalyzer, in turn, is cooled by the gases entering the apparatus.	Control of the temperature of reacting gases and product.
677,692	1901	Pauli & Krauss	SO_2, air, contact body, heat, and refrigeration.	Process (2 illustrations)	do.	Utilization of heat of reaction to warm reacting gases. Cooling of SO_3 formed.
688,020	1901	Knietsch, R.	SO_2, air, contact body, heating and cooling of gases.	Apparatus (11 illustrations) for process covered by patent No. 652,119.	The apparatus used is varied according to the richness of the gases treated, but the general scheme is to cool contact chamber by surrounding it with chamber or tubes containing a cooling medium.	Apparatus for control of reacting gases and product.
688,469	1901	do.	do.	Various forms of apparatus described in patent No. 652,119.	do.	Do.
688,470	1901	do.	do.	do.	do.	Do.
688,471	1901	do.	do.	do.	do.	Do.
688,472	1901	do.	do.	do.	do.	Do.
690,062	1901	do.	do.	do.	do.	Do.
692,018	1902	do.	do.	do.	do.	Do.
719,332	1903	Herreshoff, J. B. F.	SO_2, air, contact body, heating and cooling of gases.	Process (1 illustration)	The gaseous mixture is heated, then brought into contact with part of catalyzer, then cooled and passed over more of the catalyzer.	More efficient yield of SO_3 under these conditions.
719,333	1903	do	do.	Apparatus to bring about process described in patent No. 719,332.	do.	A more efficient apparatus for oxidation of SO_2.
723,595	1903	Ferguson, W. C.	SO_2, air, series of contact chambers, air added at intervals.	Apparatus (1 illustration) consisting of plurality of contact chambers with air inlets in connecting pipes.	The gaseous mixture is passed through a series of contact chambers, air being added after it emerges from each chamber.	More efficient yield of SO_3, due to cooling of gases and thorough mixing of same.
723,596	1903	do	do.	Process (1 illustration) for apparatus described in patent No. 723,595.	do.	An apparatus to bring about the more efficient oxidation of SO_2.
726,076	1903	LeBlanc & Krauss	SO_2, air, contact body, heat.	Process (1 illustration)	A mixture of 7 per cent SO_2, 9 per cent O, is conducted over a catalyzer at 500° C. at speed of 120 liters per minute per kilo of contact body, then through other contact chambers at successively lower temperatures.	More efficient oxidation of SO_2 due to higher temperature of first contact chamber.

731,758	1903	Daub, C.	SO_2, air, series of contact chambers, heating or cooling of the gases.	Apparatus (4 illustrations). A number of contact chambers in an upright column, each chamber connected by pipes.	The gaseous mixture is led from one chamber to another, the temperature being controlled by heating or cooling the connecting pipes.	Better control of temperature and better yield.
736,876	1903	Raynaud & Pierron	SO_2, air, 3 catalytic bodies of different oxidizing power.	Process (2 illustrations)	The gaseous mixture is led successively through 3 vessels heated to uniform temperature and having different catalytic power.	Efficient oxidation of SO_2.
742,502	1903	Schroeder, M.	SO_2, air, cooling and subsequent heating of the gases.	Process (5 illustrations).	The gases are cooled and purified and then their temperature is again raised by the heat of the fresh burner gases.	Purification of gases and economy in fuel.
751,941	1904	Raynaud & Pierron	SO_2, air, 3 contact chambers heated at different temperatures.	Process (2 illustrations)	The gaseous mixture is conducted successively through 3 contact chambers, the first heated to 300° C., the second to 500° C., and the third to 400° C.	More efficient oxidation of gaseous SO_2.
792,205	1905	Eschellmann & Harmuth.	SO_2, air, catalyzer contained in tubes, cooling of gases.	Apparatus (2 illustrations) consisting of gas-receiving chamber and lower catalytic chamber.	The gaseous mixture is led first into a chamber to cool, then into a set of tubes containing the catalyzer. The SO_3 formed is cooled by the incoming gases.	Method of controlling temperatures of gases and oxidizing same.
793,543	1905	Schroeder, Max	SO_2, air, cooling and thorough mixing of gases.	Apparatus (3 illustrations) comprising a plurality of contact chambers, adjacent contact bodies being separated by mixing spaces and passageways.	In passing through the catalytic body the gases are made to mix thoroughly. Thus the heat of the interior of the gaseous stream is transmitted to the exterior or cooler portion.	Uniform distribution of heat and thorough mixture of gases.
809,450	1906	Knietsch, R.	SO_2, air, catalyzer, cooling of gases.	Process (1 illustration)	The gaseous mixture is passed into an oxidizing chamber, the resulting SO_3 absorbed, then the residual gases are passed into a second, and if necessary, a third chamber.	Economy in platinum as a contact body.
828,268	1906	Blackmore, H. S.	Electric current, SO_2, NO_2, CO_2.	Process (6 illustrations)	A mixture of SO_2, NO_2, and CO_2 is passed up through a column, the CO_2 being reduced and SO_3 formed.	Control of temperature by the endothermic reaction CO_2 to CO.
857,389	1907	Ferguson, W. C.	SO_2, air, contact material arranged on shelves, cooling of gases.	Apparatus (2 illustrations) consisting of contact chambers provided with heat retaining covering of unequal effectiveness.	The gaseous mixture is passed through a relatively narrow tube containing shelves on which the contact body is spread.	Apparatus presenting large cooling surface and causing intimate contact of gases with catalytic agent.
1,036,473	1912	Eschellmann & Harmuth.	SO_2, air, catalyzer in 2 chambers.	Process (2 illustrations)	The gaseous mixture is first passed through a relatively thin layer of the catalyzer distributed over a considerable surface, then at a more rapid rate through a thicker layer of the catalyzer.	Efficient temperature control and distribution of catalyzer.
1,036,609	1912	Grosvenor, W. M.	SO_2, air, heat, platinum contact body.	Process (6 illustrations)	The gaseous mixture is conducted by a circuitous route into the center of the contact mass and returns by another circuitous route adjacent to to the first.	Control of temperature through mixture of gases.

TABLE VIII.—*Apparatus and processes designed to control the temperature of the gases used in the manufacture of sulphuric acid by the contact process*—Continued.

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
1,099,530	1914	Wolff, T.	SO_2, air, catalyzer, heating and cooling actions.	Apparatus (1 illustration) for cooling catalytic body and heating mixture of SO_2 and air.	The incoming gaseous mixture is passed through a preheater, the temperature of which is raised by the SO_3 formed in the contact chamber. The temperature of the gaseous mixture can be controlled by allowing only a portion to flow through the preheater.	Efficient method of controlling temperature.

TABLE IX.—*Apparatus and processes designed for the purification of the gases used in the manufacture of sulphuric acid by the contact process.*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
90,067	1869	Bigelow, A., and Baldwin, S.	SO_2, air, decrease in velocity of gaseous current.	Process (2 illustrations)	The burner gases are led into a chamber where their velocity is decreased, then into a second and larger chamber.	Scheme for settling the suspended material.
140,034	1873	Goodfellow, J. T., and Sabbaton, F.	SO_2, air, impeding of the gaseous current. Constantly renewed purifying agent.	Apparatus (7 illustrations) designed to impede the gaseous current and to renew purifying agent.	The gases are made to pursue a meandering course over the purifying agent which is being constantly renewed.	Efficient gas purifier.
670,559	1901	Hasenbach, W.	Dried air, SO_2	Apparatus (1 illustration) for drying air before admitting it to pyrites burners.	The air used for the combustion of the pyrites is thoroughly dried before admitting to the burners.	Exclusion of moisture from the contact chamber.
711,187	1902	Stone, G. C.	SO_2, air, refrigeration, and filtration.	Process (2 illustrations)	The gaseous mixture from the furnace is first cooled and then the arsenic deposited on wire gauzes covered with some filtering device.	Removal of arsenic from burner gases.
711,188	1902	do.	do.	Apparatus (2 illustrations) for conducting process described in patent No. 711,187.	do.	Do.
734,849	1903	Gin, G.	Water, sulphuric acid, refrigeration, heat, SO_2, air.	Process (2 illustrations)	The gases are first cooled, the SO_3 present is then removed by H_2SO_4, and the SO_2 is absorbed in water and then driven off by the heat of the burner gases, mixed with air, and admitted to the contact chamber.	Efficient yield of SO_3 with minimum danger to contact body.
739,108	1903	Rabe, H.	SO_2, air, cooling and filtration.	Process (1 illustration)	The gaseous mixture is first cooled, then filtered through a heavy layer of asbestos. It is then conducted over shelves containing bisulphite, and then up through a tower fed with H_2SO_4 (strong). The gases are then admitted to the contact body.	Efficient method of purifying gases.
758,222	1904	Stone, G. C.	Condensation and filtration of burner gases.	Apparatus (1 illustration) consisting of several chambers for filtering and condensing gases.	The gaseous mixture is drawn down through several compartments, the chambers being alternately filters and condensers.	Efficient gas purifier.
793,745	1905	Shields, J.	SO_2, air, constantly renewed filtering material.	Process (1 illustration)	The gases are led into a heap of the filtering material which is so arranged that the gases constantly come in contact with fresher material.	Efficient method of purifying burner gases.

TABLE IX.—*Apparatus and processes designed for the purification of the gases used in the manufacture of sulphuric acid by the contact process*—Con.

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
798,216	1905	Scharff, M., and Slama, F.	SO_2, air, iron oxide, copper oxide, or chromic oxide, manganese dioxide, or mixtures of these oxides.	Process (no illustrations)	The gases are led over one or more of the oxides heated to redness.	Removal of arsenic from the gases.
798,302	1905	do	SO_2, air, incombustible granular bodies.	do	The gaseous mixture is passed through infusible granular bodies consisting of clay, coke, furnace slag, phosphates, and silicates of the alkalies heated to 350° to 400° C.	Purification of the burner gases.
822,373	1906	Knietsch, R.	SO_2, air, steam, cooling, washing, and drying.	Process (3 illustrations)	The gases are first treated with steam, then cooled and washed, and finally dried by passing over coke impregnated with sulphuric acid.	Removal of dust arsenic and other impurities.
891,703	1908	Jonas, O.	Acetylene, tetrachloride, SO_2, air.	Process (no illustrations)	The burner gases are passed through towers fed with acetylene tetrachloride.	Removal of arsenic.
891,775	1908	do	Dichlorbenzene, SO_2, air	do	The gases are passed through towers fed with dichlorbenzene.	Do.
900,500	1908	Eschellmann, G.	Coke filters and alkaline earth hydroxide, SO_2, air.	Process (1 illustration)	The gases are first passed through a cooler, then through 2 coke filters, then up through a tower fed with milk of lime.	Removal of impurities and chlorine.
922,516	1909	Rockliff, W., and Booth, J.	SO_2, air, centrifugal force	Apparatus (6 illustrations) consisting of a longitudinal spiral deflector plate contained in a horizontal flue.	The gases in passing through the flue are submitted to the centrifugal action of the spiral deflector which throws the dust and impurities against the sides.	Method of precipitating suspended particles.
931,868	1909	Hegeler, H., and Heinz, N.	SO_2, air, refrigeration and absorption of SO_3 from gases by H_2SO_4.	Process (3 illustrations)	The gases from the furnace are mixed with cool gases of the same content of SO_2. They are then passed through a tower fed with sulphuric acid and finally dried.	Efficient method of purifying gases containing SO_2.
937,147	1909	Eschellmann & Harmuth.	SO_2, air, coke filter	Process (1 illustration)	The gases contaminated with oil from the gas pump are passed through a coke filter.	Removal of oil from burner gases.
937,148	1909	do	do	Apparatus (1 illustration) consisting of coke filter for removing oil from burner gases.	do	Do.
940,596	1909	Herreshoff, J. B. F.	SO_2, air, refrigeration, filtration, and desiccation.	Apparatus (1 illustration) consisting of a dust chamber and a series of combined coolers and scrubbers.	The gases are led first into a dust chamber, then through the series of combined scrubbers and coolers, and finally through a dryer.	Production of an efficient gas purifier.

989,801	1911	Reise, C. L.	SO_2, air, refrigeration, desiccation, lime.	Process (1 illustration)	The gases are first cooled, then dried, and finally passed over lime (CaO).	Efficient method of removing Cl, HCl, H_2S_2, and H_2SO_4.
1,016,476	1912	Cottrell, F. G.	SO_2, air, electrical precipitation.	Process (2 illustrations)	The gases are lead through a flue containing a number of pairs of screens. The first screen of each pair is fed with dilute H_2SO_4 and the second with fuming H_2SO_4. An acid mist is thus formed which is precipitated by electric charges.	Precipitation of dust and impurities out of gases.
1,028,880	1912	Howard, H.	SO_2, air, refrigeration, and strong sulphuric acid.	Process (1 illustration)	The gases are first dried by cooling and then by passing through strong H_2SO_4.	Means of removing moisture without excessive use of sulphuric acid.
1,113,437	1914	Herreshoff, J. B. F.	SO_2, air, cooling action	Process (5 illustrations)	The gases, after being washed with sulphuric acid (40°B.), are cooled from 200° to 100° F., thus precipitating much of the moisture.	Economy in acid necessary to dry gases.

TABLE X.—*Apparatus and processes designed to absorb the SO_3 formed in the manufacture of sulphuric acid by the contact process.*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
695,180	1902	Stone, G. C.	SO_3, cooling action and dilute H_2SO_4.	Apparatus (4 illustrations) consisting of cooled tubes down which dilute H_2SO_4 flows. Tubes contain dams to delay flow.	SO_3 from contact chamber is led up through the cooled tube down which dilute sulphuric acid flows.	Efficient absorptive apparatus for SO_3.
722,981	1903	Herreshoff, J. B. F.	Sulphuric acid of constant strength, SO_3.	Process (1 illustration)	SO_3 produced in contact chamber is passed into sulphuric acid (90 per cent) maintained at constant strength by addition of water.	More efficient method of absorbing SO_3.
737,625	1903	do	SO_3, sulphuric acid of constant strength.	do	After absorbing SO_3 from the gases issuing from the contact chamber part of the acid is removed and the remainder automatically diluted and restored for absorptive purposes.	Automatic regulation of absorptive medium.
737,626	1903	do	do	Apparatus (1 illustration) for method covered by patent No. 737,625.	do	Do.
789,634	1905	Schroeder, M.	SO_3, dilute H_2SO_4 percolating through sand and quartz or other acid-proof material.	Process (2 illustrations)	SO_3 from contact chamber is passed up through a tower containing acid-proof packing over which dilute H_2SO_4 flows.	Intimate contact with the H_2SO_4 absorbs the SO_3 from gases.
800,218	1905	Knietsch, R.	SO_3, H_2SO_4 containing at least 27 per cent free SO_3.	Process (no illustrations)	SO_3 from contact chamber is passed into H_2SO_4 containing at least 27 per cent free SO_3. This acid does not attack iron.	Method of obtaining H_2SO_4 free from iron.
816,918	1906	do	SO_3, H_2SO_4 containing between 97 and 99 per cent H_2SO_4.	Process (1 illustration)	SO_3 from contact chamber is passed into H_2SO_4 containing from 97 to 99 per cent H_2SO_4. This acid does not attack iron.	Production of H_2SO_4 free from iron.
866,843	1907	Cottrell, F. G.	SO_3, water in form of spray	Process (1 illustration); apparatus (2 illustrations). Centrifugal appliance consisting of rotating shell having plurality of concentrically placed cylinders.	SO_3 from contact chamber is sprayed with water, liquid particles of H_2SO_4 being formed.	Absorption of SO_3 and precipitation of H_2SO_4.
866,844	1907	do	do	do	do	Do.
894,792	1908	Eschellmann & Harmuth.	SO_3, absorptive medium, cooling action.	Apparatus (2 illustrations) consisting of a plurality of absorption chambers down the walls of which an absorbing liquid flows.	SO_3 from contact chamber is led through a plurality of absorption chambers adapted to contain an absorbing liquid. The walls of the chambers are cooled.	Efficient absorption apparatus.

1,002,824	1911	Cox, I. J.	SO_3, concentrated H_2SO_4, cooling action.	Process (1 illustration)	SO_3 from contact chamber is passed up through a coke column down which strong H_2SO_4 (cooled) flows. The acid then goes to cooler and is again distributed through the tower.	Acid for efficient absorption of SO_3.
1,013,638	1912	Briggs & Merriam	SO_3, H_2SO_4 (97 to 99.5 per cent) cooled.	do.	SO_3 from contact chamber and air in passing up through an absorption tower meet cooled H_2SO_4 flowing down the tower. The temperature of the tower is regulated by a film of water flowing down the exterior walls of the tower.	A process for the efficient absorption of SO_3.
1,082,301	1913	do.	do.	Apparatus (1 illustration) for carrying out process described in patent No. 1,013,638.	do.	An apparatus for the efficient absorption of SO_3.

TABLE XI.—*Apparatus and processes for the more efficient mixing of the gases used in the manufacture of sulphuric acid by the contact process.*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
384,841	1888	Hamsch & Schroeder	Air and SO_2 under pressure, catalyzer.	Process (2 illustrations)	A mixture of air and SO_2 is compressed and passed over heated platinum.	Compression tends to mix gases and produce more efficient yield.
677,670	1901	Krauss & Wach	Air and SO_2, admitted at various points in system, catalyzer.	Apparatus (1 illustration) consisting of contact chamber with gas ingress at two or more points.	Air and SO_2 are admitted at various points in the contact chamber.	Control of temperature and efficient mixture of gases.
688,020	1901	Knietsch, R.	SO_2, air, mixing and cooling.	Apparatus (2 illustrations)	The gaseous mixture is passed through a number of small pipes.	Apparatus for obtaining an efficient mixture and controlling temperature of gases.
688,469	1901	do.	SO_2, air, mixing and heating of entering gases, and cooling of SO_3 formed.	Apparatus (2 illustrations) consisting of inclosure containing contact body and cooling fluid conduit. The cooling fluid after absorbing the heat of reaction is used to heat the incoming gases.	The gaseous mixture is led through a number of small pipes containing the contact body and thus thoroughly mixed. The heat of the reaction is used to heat the gases entering the tubes.	Economy in fuel, mixing of gases, and control of temperature.
688,470	1901	do.	do.	Apparatus (2 illustrations) consisting of receptacle for catalyzer and inclosure for cooling medium adjacent to contact chamber, also regulator for controlling temperature of cooling medium.	The incoming gases are heated by the medium which has absorbed the heat from the SO_3 formed. A temperature regulator prevents excessive heating or cooling.	An apparatus for the efficient mixing of the gases and control of their temperature.

TABLE XII.—*Miscellaneous apparatus and processes for the production of SO_3 or H_2SO_4 by the contact process.*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
700,249	1902	Sébellot, A. M. G.	SO_2, air, steam, spongy platinum, fibrous asbestos, pumice.	Apparatus (2 illustrations) consisting of vertical casing containing a perforated partition at bottom on which is supported a thick layer of asbestos and pumice. A series of plates containing platinized asbestos.	A mixture of air, SO_2, and steam is admitted to the upper part of chamber containing the contact body. The H_2SO_4 produced proceeds downward through the asbestos and pumice stone and is drawn off at the base.	Efficient oxidation of SO_2 and condensation of H_2SO_4.
875,909	1908	Heinz & Chase	SO_2, oxides of nitrogen, catalytic agent.	Process (2 illustrations)	The gases are mixed with the oxides of nitrogen and conducted successively through a dust flue, a Glover tower, and a Gay-Lussac tower. The residual gases are then filtered and heated and passed over some contact mass.	Combination of chamber and contact process, requiring no elaborate purifying devices.

TABLE XIII.—*Apparatus and processes for utilizing the gases from smelters in the manufacture of sulphuric acid by the chamber process.*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of process or apparatus.
891,116	1908	Tufts, G. J., and Bramard, E. E.	SO_2 supplied from burning S in addition to that from the furnaces.	Apparatus (1 illustration) comprising an equalizing chamber of relatively large area for rendering the SO_2 from the smelters more nearly uniform in temperature and concentration; also a burner for sulphur.	The percentage of SO_2 in the smelter gases is kept constant by admitting either air or SO_2 into the equalizing chamber.	Apparatus for maintaining SO_2 in furnace gases at constant temperature and in constant quantity.
962,493	1910	Channing & Falding	do.	Process (2 illustrations)	The gases from a number of furnaces are led into a common chamber or reservoir and mixed. By admitting air or SO_2 from an auxiliary source a mixture of constant composition is maintained.	Production of H_2SO_4 from smelter gases.
1,046,915	1912	Wedge, U.	SO_2, water, heat.	Process (1 illustration)	The gases from the smelters are led over quiescent bodies of water maintained at a comparatively low temperature. The water is then heated and agitated and the SO_2 driven off.	Absorption of SO_2 from smelter gases and its subsequent utilization.

TABLE XIV.—*Apparatus and processes designed to mix and cool the mixture of gases used in the manufacture of sulphuric acid by the chamber process.*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
1,303	1839	Hargreaves, J.	SO_2, air blast, steam, oxides of nitrogen.	Process (1 illustration)	The furnace gases are blown by an air blast and steam down through a pipe to the bottom of a tank. The gases then pursue a meandering course up through this tank.	Means of making H_2SO_4.
114,042	1871	Ravenel, St. J.	SO_2, air, nitrate of soda, water, cooling action.	Apparatus (1 illustration) consisting of a cooling tower, a chamber, a smaller compartment, and a final tower.	The gaseous mixture is led through the cooling tower, then into the acid chamber, then into the smaller chamber, and finally the last traces of H_2SO_4 are removed in the last tower.	The method of producing H_2SO_4 with less chamber space.
349,241	1886	Thyss, J. J.	SO_2, air, steam, nitrate of soda.	Apparatus (2 illustrations) consisting of towers fitted at intervals with horizontal perforated lead plates.	The gases are led down through a series of the towers, meeting a steam current. The numerous contacts tend to condense the H_2SO_4 formed.	Combined condensers and acid-forming chambers.
345,140	1886	Hughes, J.	SO_2, air, water spray, oxides of nitrogen.	Process (1 illustration)	The hot furnace gases meet a spray of water, which is thus volatilized. The gaseous mixture is then led through a flue containing water and into a chamber, where H_2SO_4 is formed.	Economy in fuel and efficient method of producing H_2SO_4.
353,222	1886	do.	do.	Apparatus (3 illustrations) consisting of a flue containing water, and chamber for production of H_2SO_4.	do.	Apparatus for carrying out process described in patent No. 345,140.
446,060	1891	Delplace, E. & J.	SO_2, air, oxides of nitrogen, mixing and cooling action, water.	Apparatus (4 illustrations) consisting of annular lead chamber provided with two gas inlets, and containing distributing tubes at intervals to convey the hot gases from the upper to lower part of chamber.	The gases are given a rotary motion, which tends to mix them thoroughly.	More efficient method of producing H_2SO_4 due to better mixing of gases.
485,126	1892	Lunge, G.	Oxides of nitrogen, mixing and cooling action, water, SO_2, air.	Apparatus (8 illustrations) consisting of plates contained in towers so arranged that the gases are continually impinging on a film of cool dilute acid. The acid splashes from one layer of plates to another.	The hot gases are mixed and cooled by ascending the plate column and meeting the dilute H_2SO_4 dripping down the tower.	Apparatus for the cooling and mixing of gases and condensation of H_2SO_4 formed.

TABLE XIV.—*Apparatus and processes designed to mix and cool the mixture of gases used in the manufacture of sulphuric acid by the chamber process*—Continued.

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
546,596	1895	Pratt, N. P.	SO_2, air, oxides of nitrogen, mixing and cooling action, water.	Process and apparatus (6 illustrations). Apparatus consists of an auxiliary cooling tower and means for withdrawing part of the gases from the chambers and reintroducing them into the front of the system.	The gases, after traversing the first chamber, are in part withdrawn and reintroduced into the front of the chamber. The remainder of the gas proceeds to a cooling tower fed with dilute H_2SO_4 and packed with quartz.	Apparatus and process for thoroughly mixing and cooling gases and precipitating H_2SO_4 formed.
598,351	1898	Staub, A.	do.	Apparatus (12 illustrations) consisting of a series of towers packed with especially constructed acid-resisting bodies.	The gases make their way up the towers and are both mixed and cooled by acid-proof packing.	Efficient yield due to character of packing material.
652,687	1900	Pratt, N. P.	do.	Apparatus (2 illustrations) consisting of an acid-resisting fan connected with the flue leading from the Glover tower and with the chambers.	The gases, after traversing the first chamber, are drawn by the fan into the flue leading from the Glover tower and thus mixed with the fresh gases from the furnaces.	Device for accelerating the reactions.
652,689	1900	do.	do.	Apparatus (1 illustration) consisting of acid chamber with flue leading therefrom and connecting with generator of acid-making gases. Two fans are provided for withdrawing gases and reintroducing them into system.	The partially spent gases are reintroduced into the front of the system and discharged against the current caused by an accelerated draft.	Apparatus for thoroughly mixing gases and accelerating reactions.
652,690	1900	do.	do.	Apparatus (3 illustrations) consisting of blower connected with rear of systems and also with Glover tower, and a flue for reintroduction of partially spent gases, which are mixed with the fresh gases from the furnace.	The partially spent gases and the fresh gases from the Glover tower are mixed and blown into the first chamber.	Do.
688,538	1901	Meyer, T.	do.	Apparatus (2 illustrations) consisting of circular chamber with gas inlet near the top of side wall and outlet at center of chamber bottom.	The mixture of gases is admitted at a tangent and pursues a circular spiral course. The spent gases gradually sink toward the center of the chamber's base and are withdrawn.	Apparatus to produce thorough mixture of gases and control temperature.

688,872	1901	....do.	....do.	Process (2 illustrations) carried out by apparatus described in patent No. 688,538.	....do.	Process to produce thorough mixture of gases and control temperature of system.
715,142	1902	Pratt, N. P.	....do.	Process (2 illustrations).	The reacting gases are cooled by surrounding the flues between the chambers with cooling devices. The uncombined gases are withdrawn from the rear of system and reintroduced with fresh gases into the first chamber.	Efficient method of mixing gases and controlling temperature of these gases.
728,914	1903	Heinz, N. L.	....do.	Apparatus (4 illustrations) consisting of an arrangement of 2 flues for each chamber. The flues enter the chamber from opposite sides at different levels.	The gases are introduced at opposite sides of the chambers at different levels and made to proceed transversely in their course through the chambers.	Apparatus for more efficient mixing of gases.
736,087	1903	Graham, J. G.	....do.	Apparatus (11 illustrations) consisting of longitudinal trough-shaped contact pieces arranged transversely in tower or chamber.	The gases are passed into a chamber or tower packed with the acid-resisting bodies. The hollow sides of the contact pieces are disposed toward the inflowing gases.	Efficient packing material for towers.
765,834	1904	Hegeler & Heinz.	....do.	Apparatus (1 illustration) consisting of fan in main flue between Glover tower and first chamber; another fan in smaller branch flue for reintroducing gases into Glover tower.	The gases after leaving the Glover tower are in part withdrawn and reintroduced into the Glover tower.	Apparatus for obtaining thorough mixture of gases.
767,335	1904	Evers, R.	....do.	Apparatus (15 illustrations) consisting of denitrating tower, means of providing steam and hot air to said tower, a condensing tower, and means for mixing and cooling gases.	The acid is denitrated in first tower by means of steam and hot air. The gases are cooled, mixed, and the H_2SO_4 condensed in the second chamber.	Combined denitrating and condensing plant.
848,631	1907	Cellarius, R.	....do.	Apparatus (2 illustrations) consisting of turret lined with coke and containing a turbine which is operated by steam-blast.	Gases enter tower at bottom and are thoroughly mixed and the acid formed precipitated by the turbine.	Apparatus for mixing of gases and precipitation of H_2SO_4 formed.
852,390	1907	Liliine, I. P.	....do.	Apparatus (3 illustrations) consisting of chamber containing series of vertical air-cooled lead pipes extending from top to bottom. Partition walls having numerous transverse openings are disposed between each set of pipes.	The gases in passing through the chamber are cooled by the lead pipes, the nitrosulphuric acid formed is then decomposed, the H_2SO_4 precipitated, and the oxides of nitrogen thus liberated.	Apparatus for more efficient production of H_2SO_4 at less cost.

TABLE XIV.—*Apparatus and processes designed to mix and cool the mixture of gases used in the manufacture of sulphuric acid by the chamber process*—Continued.

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
860,968	1907	Eliel, O. H.	SO_2, air, oxides of nitrogen, mixing and cooling action, water.	Apparatus (3 illustrations) consisting of several chambers connected in series, the chambers having their greatest extension arranged horizontally. The exit and entrance of chambers are at the same end.	The gases enter the first chamber from the Glover tower in the usual way. A jet of steam in the flue accelerates their velocity. The gaseous steam strikes the rear of the chamber and is thrown back toward the front end, where it is discharged.	Efficient mixture of gases by means of apparatus described.
1,022,493	1912	Meigs, C. C.	SO_2, air, oxides of nitrogen, water, compression and expansion of gases, cooling action.	Apparatus (2 illustrations) consisting of chambers containing air-cooled deflector.	The burner gases enter a rectangular lead chamber and striking the concave sides of an air-cooled deflector are thrown against the sides of the chamber and into the currents of gas passing toward rear of chamber.	Apparatus for thoroughly cooling and mixing reacting gases.
1,057,149	1913	Heinz, N. L.	Oxides of nitrogen, water, and air introduced at intervals into system.	Process (2 illustrations)	The gaseous mixture and steam are treated, in passing through the system, with such regulated quantities of air introduced at intervals that a uniform pressure and movement of the gases is maintained and an amount of oxygen supplied equal to that consumed by the reactions.	Process of accelerating and completing reactions in the chambers.
1,104,590	1914	Wedge, U.	Oxides of nitrogen, water, cooling action.	do	The gases are led at high speed through a plurality of lead chambers or towers of relatively small cross-section and presenting 310 feet of cooling surface for each cubic foot of chamber space.	Process for oxidizing SO_2 to H_2SO_4 in ho diluted furnace gases.
1,112,424	1914	McFarlane, E. H.	do	Apparatus (1 illustration) consisting of blower and device responsive to variations in volume of gases and controlling speed of blower.	A forced draft is induced in the gaseous mixture by a blower, the speed of which is automatically controlled by the volume of the gases passing through the system.	Apparatus for accelerating reactions in lead chambers.
1,112,546	1914	Mills, W., and Packard, C.	do	Apparatus (1 illustration) consisting of a chamber shaped like a frustum.	The chamber is so arranged that water flows over the outside walls, thus cooling the reacting gases.	Apparatus for cooling chamber gases.

TABLE XV.—*Apparatus and processes designed primarily to effect economy in the consumption of niter used in the manufacture of sulphuric acid by the chamber process.*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
292,054	1884	Rigby, J. S.	Solution of $NaNO_3$, H_2SO_4	Apparatus (1 illustration) consisting of niter pots into which H_2SO_4 and a solution of $NaNO_3$ can be led.	By regulating the supplies of acid and $NaNO_3$ a steady stream of oxides of nitrogen is furnished to the acid system.	Apparatus for providing oxides of nitrogen in proper quantities.
292,078	1884	Walsh, M. A.	None.	Apparatus (3 illustrations) consisting of an improved Glover tower so arranged that the descending acid can not collect in any pockets and act as an absorber for freshly freed oxides of nitrogen.	The tower and packing so arranged that there are no pigeonholes in which cooler acid can collect and absorb the oxides of nitrogen set free by the hot-burner gases.	Improvement in construction of Glover tower and consequent saving of niter.
350,416	1881	Benker, F., and Lasne, H.	N_2O_4, SO_2, air, water	Process (no illustrations)	The gases after leaving the lead chambers are mixed with SO_2, which reduces the N_2O_4 to N_2O_3, the latter compound being readily absorbed in the Gay-Lussac tower.	Economy in niter consumption.
375,121	1887	Chappell, F. W.	None.	Apparatus (8 illustrations) consisting of a series of cups (lead) supported from framework of towers and attached to lead top by distributing pipes. Inverted glass tumblers placed in these cups on spiders form hydraulic seals.	The pipes which form the communication between the cups and the tower project above the base of the former, thus forming a ring in which the acid collects. The glass tumblers inverted and placed in these rings form the hydraulic seal. The overflow from the rings runs into the tower.	An apparatus for the uniform distribution of acid to the Glover and Gay-Lussac towers.
378,289	1888	....do.	None.	Apparatus (8 illustrations) consisting of a reactionary wheel which distributes acid against a ring which in turn distributes it to the various pipes. (Used in connection with apparatus described in patent No. 275,121.)	The reactionary wheel in revolving uniformly distributes the acid to the various pipes feeding the tower.	Apparatus for uniformly distributing acid to Glover and Gay-Lussac towers, and consequent saving of niter.

388,406	1888	Frazier, S.	None.	Apparatus (1 illustration) consisting of a reactionary wheel provided with emergency distributors for any excess of acid which may be supplied to the apparatus.	The reactionary wheel in revolving uniformly distributes the acid to the pipes feeding the tower. By means of emergency distributors the supply of acid can be greatly increased.	Do.
659,236	1900	Johnson, A. C.	Oxygen-hydrogen mixture in proportions to form water, SO_2, air.	Process (3 illustrations).	The gaseous mixture is passed into a chamber in the usual way. Oxygen and hydrogen are also introduced into this same chamber and continually exploded by means of an electric spark.	Method of forming and precipitating H_2SO_4 without use of oxides of nitrogen.
725,427	1903	Eliel, O. H.	None.	Apparatus (4 illustrations) consisting of new form of Glover tower having three separately packed sections	The gases from the furnace or burners are drawn down through the tower in three streams along with the sulphuric acid to be denitrated and concentrated.	Improvement in construction of Glover tower, resulting in saving in niter consumption.
755,247	1904	Salom, P. G.	Electric current, SO_2, air.	Process (1 illustration).	The SO_2 and air are passed through a series of independent but communicating receptacles each of which constitutes an electrolytic cell. Oxidation takes place and the H_2SO_4 formed is then drawn off.	Process for making H_2SO_4 without the use of oxides of nitrogen.
850,820	1907	Derrig, P. J.	$NaNO_3$ solution, H_2SO_4, SO_2, air.	Apparatus (2 illustrations) consisting of lead shell packed with quartz or coke down which a solution of $NaNO_3$, and H_2SO_4 flows.	Part of the gases from the pyrites burners is made to pass through this coke column, thereby being nitrated.	Apparatus for nitrifying SO_2 used in chamber process.
898,390	1908	Pauling, H.	Dilute HNO_3, nitrosulphuric acid.	Process (1 illustration).	The anode compartment of a suitable electrolyzer is filled with nitrosulphuric acid and the kathode compartment with dilute HNO_3. On electrolyzing the liquid the oxides of nitrogen liberated at the kathode are led into and absorbed in the anode chamber.	Process for regeneration and concentration of dilute acid containing oxides of nitrogen.
900,688	1908	Bender, O.	SO_2, O, and N, carbonaceous fuel, oxyhydrogen flame.	Process (2 illustrations).	The gaseous mixture (no oxides of nitrogen) is led through a carbonaceous fire. Partly dissociated steam is then introduced into the mixture and the free H_2 and O in combining heat the gases still higher. The gases are then cooled by steam.	Production of H_2SO_4 without niter in small chamber space.
904,147	1908	Petersen, H.	Cold nitrous vitriol (55° B.), SO_2, air, water.	do.	The gases after leaving the last chamber are brought into contact with cold nitrous vitriol (55° B.) before proceeding to the Gay-Lussac tower.	Process for preventing escape of SO_2 and oxides of nitrogen.

TABLE XV.—*Apparatus and processes designed primarily to effect economy in the consumption of niter used in the manufacture of sulphuric acid by the chamber process*—Continued.

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
908,696	1909	Petersen, H.	Two supplies of nitrous vitriol of different strengths and two supplies of Glover acid of different strengths, SO_2, air, water.	Process (5 illustrations)	The gaseous mixture is passed into contact with two supplies of nitrous vitriol, then through the chambers in the usual way, and finally in contact with two supplies of Glover acid of different strengths.	Efficient method of oxidizing SO_2 and recovering oxides of nitrogen.
1,068,021	1913	Tarand, A., and Truchot, P.	Water solution of Na_2CO_3, SO_2, air, water.	Process (1 illustration)	The gases after leaving the Gay-Lussac tower are led up through a tower packed with acid-resisting material down which water trickles. The gases are then led successively through two towers into which a solution of Na_2CO_3 is sprayed. The $NaNO_3$ resulting is then sprayed into the chambers.	Process for recovery of last traces of oxides of nitrogen and sulphuric acid.

TABLE XVI.—*Apparatus and processes designed primarily to reduce the amount of chamber space required in the manufacture of sulphuric acid by the chamber process.*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of process or apparatus.
86,881	1869	Tait, A. H.	Liquid SO_2 and NO_2 free from nitrogen, steam.	Process (4 illustrations).	The SO_2 from the pyrites burners is liquefied and thus freed from N; it is then introduced together with NO_2 under pressure into a chamber into which air and steam are also forced. The NO_2 is oxidized to NO_3, which is liquefied, and mingling with the liquid SO_2, oxidizes the latter.	Efficient production of H_2SO_4 in small amount of chamber space.
143,202	1873	Thomson, E., and Green, W.	SO_2, air, nitric acid, cooling.	Apparatus (5 illustrations) consisting of two towers, one for the reactions and the other for absorbing the oxides of nitrogen.	The burner gases are admitted at two points in the reaction tower which is fed with HNO_3. The condensed acid is drawn off and the oxides of nitrogen absorbed from the residual gases by passing through an absorption tower fed with water.	Production of purer and more concentrated H_2SO_4 with less chamber space.
535,882	1895	Barbier, E. J.	HNO_3, SO_2, air, heat.	Apparatus (5 illustrations) consisting of three reaction towers containing piles of perforated pots, and one Gay-Lussac tower.	The gases are led from the furnace through three towers filled with perforated pots and fed with HNO_3. The base of each tower consists of a perforated plate under which there is an acid pan heated by a separate fire.	Efficient apparatus for producing H_2SO_4 without use of large chambers.
652,688	1900	Pratt, N. P.	SO_2, air, oxides of nitrogen, cooling and mixing.	Apparatus (1 illustration) consisting of two series of towers (in lieu of chambers) packed with some suitable acid-resisting bodies. A flue connects the first of the second series with the last of the first series. A blast mechanism is contained in the flue.	The gaseous mixture is drawn through the first series of packed towers or converters. Part of the gas then goes to the Gay-Lussac tower and part is drawn through a second series of converters by means of a flue connecting the two series.	Substitute for lead chambers.
729,643	1903	Neumann, Max	SO_2, air, oxides of nitrogen, water heating and cooling.	Process (5 illustrations).	The furnace gases are drawn through a plurality of Glover towers and through alternating heating and cooling zones intermediate of said towers.	Efficient production of H_2SO_4 without employing lead chambers.
765,520	1904	Stinville, A. L.	SO_2, air, oxides of nitrogen, H_2SO_4 (3° to 5° B. below that produced on chamber walls), cooling.	Process (1 illustration).	Cool dilute H_2SO_4 in the bottoms of a plurality of chambers serves to cool and condense H_2SO_4 formed, and to furnish part of water required for system.	Economy in chamber space and cost of construction.

TABLE XVI.—*Apparatus and processes designed primarily to reduce the amount of chamber space required in the manufacture of sulphuric acid by the chamber process*—Continued.

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
932,771	1909	Falding, F. J.	SO_2, air, oxides of nitrogen, water.	Apparatus (6 illustrations) consisting of the usual chamber plant, except that the chambers are one and one-half times higher than their horizontal dimensions and are not connected in series.	The mixture of gases is led from the Glover tower into the lead chambers near the top. A hot zone of the reacting gases is thus formed at the top of the chambers. The spent gases gradually settle to the bottom and are withdrawn.	Efficient production of H_2SO_4 due to the segregation of the reacting gases from the spent gases.
1,012,421	1911	Opl, C.	Nitrosulphuric acid, SO_2, water, compressed air.	Process (2 illustrations).	Part of the burner gases, together with compressed air, is made to lift the nitrosulphuric acid from the acid eggs, said acid is then sprayed from the tops of a number of reaction towers through which the bulk of the burner gases is led.	Production of H_2SO_4 without use of ordinary lead chambers, thus economizing in chamber space.
1,048,953	1912	Fulda, W.	SO_2, air, HNO_3, water.	Process (1 illustration).	The burner gases are treated with HNO_3. The reduced HNO_3 is then regenerated by passing down a plurality of oxidizing towers.	Production of H_2SO_4 without use of lead chambers (ordinary) and without loss of HNO_3.

TABLE XVII. *Apparatus and processes designed primarily for the concentration of the sulphuric acid manufactured by chamber process.*

Patent No.	Year.	Patentee.	Reagent used.	Apparatus employed.	Treatment.	Object of process or apparatus.
541,041	1895	Falding, F. J.	Heat of burner gases	Process and apparatus (6 illustrations) consisting of concentrating tower.	The acid from the Glover tower is allowed to trickle down an absorption tower filled with some suitable packing material.	Production of more concentrated H_2SO_4.
699,011	1902	Quinan, W. R.	do	Apparatus (6 illustrations) consisting of a concentrating flue arranged in a series of steps.	The acid from the Glover tower flows down the flue in a thin stream, being exposed to the action of the burner gases, the heat of which concentrates the acid.	Production of H_2SO_4 of 66° B.
752,677	1904	Heinz, N., and Hegeler, H.	Oxides of nitrogen, SO_3, heat of burner gases.	Process (2 illustrations)	The gases are withdrawn from any part of the system and mixed with the gases entering the Glover tower.	Production of more concentrated H_2SO_4 due to absorption of SO_3 from gases.
768,108	1904	Zanner, Adolf	Heat of burner gases	Apparatus (3 illustrations) consisting of an enlarged flue (containing vessels of H_2SO_4) between the burners and the Glover tower.	The heat of the burner gases is utilized to concentrate H_2SO_4. The latter exerts a cooling action on the gases and also furnishes water to the system.	Production of more concentrated H_2SO_4.
963,174	1910	Proelss, O.	do	Process (3 illustrations)	The burner gases are conducted in two independent streams through a denitrating apparatus and a concentrator. The two streams are then brought together and passed through a cooler in contact with dilute H_2SO_4 containing oxides of nitrogen. The gases are finally admitted to the chambers.	Production of concentrated H_2SO_4.
963,175	1910	do	do	Process (1 illustration)	The burner gases are conducted through a concentrating tower supplied with ordinary H_2SO_4. The concentration of the acid is carried to the point where the impurities are deposited.	Production of more concentrated and purer H_2SO_4.
989,537	1911	do	do	Apparatus (2 illustrations) consisting of a plurality of towers for concentrating H_2SO_4, and means for supplying acid to said chambers, also cooling apparatus.	Apparatus for carrying out process described in patent No. 963,175.	Apparatus for production and concentration of H_2SO_4.

TABLE XVIII.—*Miscellaneous apparatus and processes for the manufacture of sulphuric acid by the chamber process.*

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
130,432	1872	Jackson, D.	SO_2 from S, HNO_3, air, water.	Apparatus and process (4 illustrations) consisting of a special furnace for burning S and chambers containing screens to filter out fine S.	The mixture of gases and finely divided S are led through a chamber containing screens. The gases then go to the denitrating chamber, where their heat drives off the oxides of nitrogen from H_2SO_4 already formed. The gases then go to the conversion chamber.	Efficient production of H_2SO_4 from S by apparatus described.
150,095	1874	Sprengel, H.	Water or acid in form of spray.	Process (no illustrations).	Water or acid is sprayed into the reaction chambers instead of steam.	More efficient method of precipitating the sulphuric acid formed.
230,501	1880	Sébilot, A. G.	Ore treated with sulphuric acid, heat, air, steam.	Apparatus (2 illustrations) consisting of a special furnace.	The ore is treated with H_2SO_4 and heated in a furnace, resulting in the formation of sulphates and evolution of SO_2 and H_2SO_4. The SO_2 is oxidized by mixing with air and steam.	Recovery of H_2SO_4 from treatment of ores.
233,680	1880	Labois, E. & L.	Heat.	Process and apparatus (3 illustrations) for the production of CS_2 and H_2SO_4.	The pyrites are first heated and 15 per cent of their sulphur content driven off; the remaining material is then dumped into a grate and the SO_2 burned out.	A method and process for the production of CS_2 and H_2SO_4 from pyrites.
268,793	1882	Haworth, E.	Absorption by and subsequent drawing off of gases from water.	Process (2 illustrations).	The mixture of gases is allowed to bubble through water. The solution of SO_2 is then heated by a steam coil and thus driven off. The water is returned to the first tank and used again.	Purification of SO_2.
270,763	1883	Dotterer, T. D.	SO_2, air, steam, water.	Apparatus (1 illustration) consisting of a tower connected with a pipe which leads into a tank; the tank is connected with a fume chamber which opens under a pile of coke.	The gases after leaving the lead chamber are drawn up through a long pipe (into which a jet of steam is played) into a tank sprayed with water. The vapors escaping condensation are then led down into a fume chamber and up through a hollow coke pile sprayed with water.	Apparatus for the absorption and condensation of injurious fumes.
308,289	1884	Terrell, T.	S and $FeSO_4$, heat.	Process (no illustrations).	A mixture of S and $FeSO_4$ is first heated and then burned, resulting in the formation of SO_2, SO_3, and Fe_2O_3. The SO_2 is then converted into H_2SO_4 in the usual way.	Efficient method of making Fe_2O_3 from $FeSO_4$ and H_2SO_4.

TABLE XVIII.—*Miscellaneous apparatus and processes for the manufacture of sulphuric acid by the chamber process*—Continued.

Patent No.	Year.	Patentee.	Reagents used.	Apparatus employed.	Treatment.	Object of apparatus or process.
325,262	1885	McNab, J.	Oxides of nitrogen supplied from auxiliary tower.	Process (2 illustrations)	Nitrous vitriol is fed into a tower down which it trickles, meeting a current of steam which denitrifies it. The oxides of nitrogen thus freed are led into the last chamber or to any other.	Method of restoring sick or pale chambers quickly.
325,263	1885	do.	do.	Apparatus (2 illustrations) consisting of auxiliary tower for carrying out process described in patent No. 325,262.	do.	Apparatus for restoring sick or pale chambers quickly.
357,107	1887	Sprengel, H. J. P.	Waste steam	Process (1 illustration)	Waste steam from the exhaust pipe is run into the lead chamber to supply the water necessary in the formation of H_2SO_4 by the chamber process.	Utilization of waste steam and a consequent saving of fuel.
477,755	1892	Hanisch, G. E.	Some salt which does not react with H_2SO_4, such as Na_2SO_4 or $CaSO_4$.	Process (no illustrations)	The H_2SO_4 is mixed with the salt in the quantity necessary to have the latter take up water from the former sufficient to produce a crystallized mass.	Solidification of acid to facilitate shipment of same.
694,024	1902	O'Brien, A. P.	Heat	Apparatus (3 illustrations) consisting of niter oven so arranged in a casing that the latter also serves as a dust chamber.	The niter ovens are heated by means of the furnace gases. Means are provided for drawing off the niter cake.	Niter oven which serves as dust chamber, and which can be readily cleaned.
798,524	1905	McNab, J.	None	Apparatus (14 illustrations) consisting of improved roasting kiln for pyrites.	Kiln is constructed in such a way as to avoid danger of collapsing.	Improved furnace for burning pyrites.
825,057	1906	Johnson, W. McA.	Sulphuric acid in electrolytic cell, SO_2.	Process (3 illustrations)	An electric current is passed through dilute sulphuric acid into which SO_2 is led.	Method of obtaining H_2SO_4 without employing oxides of nitrogen or other catalytic agent.
873,070	1907	Nibelius, A. W.	A volatile solvent for H_2SO_4.	Process (1 illustration)	Niter cake is ground and treated with a volatile solvent for H_2SO_4. After filtering, the volatile substance is distilled off.	Process of obtaining H_2SO_4 from niter cake.
908,400	1908	Eggleston, J. E.	H_2S and means for burning it and oxidizing resulting SO_2.	Apparatus (2 illustrations) consisting of burner for H_2S in connection with a series of oil stills and means (chamber and Glover tower) to oxidize SO_2.	Oil containing sulphur is passed through a series of stills. The H_2S evolved is oxidized to SO_2 and the SO_2 then treated by the chamber process.	Apparatus for separating and oxidizing sulphur contained in oil.

928,844	1909	De Brailles, G. C.	H_2SO_4, SO_2, under pressure, granules of coke and antimonated lead packed in the inner compartment of a two-chamber cell, electric current.	Process (1 illustration)	A mixture of H_2SO_4 and SO_2 under pressure and at 45° B. is run into both chambers. An electric current is passed through the cell, which decomposes the water contained in the acid mixture. The hydrogen from the cathode reduces the SO_2, and the oxygen at the anode oxidizes the SO_2 to H_2SO_4.	Production, concentration, and purification of H_2SO_4.
909,578	1909	Gaillard, A.	Water in form of spray and means to introduce it into system.	Apparatus (1 illustration) consisting of a lead chamber having circular holes cut in its top into which are sealed lead cones. Jet nozzles passing inwardly through said cones, and receptacles below the cones to catch condensed water.	The height of the water sprays from the bottom of the chamber is thus increased, and the condensed water being collected in the receptacles below the cones is led out of the chamber without diluting the H_2SO_4.	Apparatus for introducing water into the chamber.
981,103	1911	Moritz, R.	None.	Apparatus (8 illustrations) consisting of framework and means to support acid chambers thereto.	The framework is so constructed that it does not come into contact with the chamber's sides.	Improved construction of chambers.
1,018,040	1912	Eggleston, J. E.	Heat, steam, H_2S, and means to oxidize latter.	Process (2 illustrations)	Petroleum containing sulphur compounds is first heated to 300° to 500° F. in a series of stills and then exposed to action of steam. H_2S evolved is burned and treated by chamber process.	Process for utilizing sulphur in petroleum.
1,018,374	1912	Robinson, C. I.	Heat, H_2S, and means to oxidize latter.	Process (1 illustration)	Petroleum containing sulphur is heated to about 500° F. The volatile products are passed through a condenser. The H_2S evolved is collected in a gasometer and subsequently burned to SO_2 and oxidized in chambers.	Process for utilizing sulphur in crude oil and purifying latter.
1,106,999	1914	Wedge, W.	Acetate of an alkali or some other metal in acid solution, iodine solution.	Process (no illustrations)	The gases are tested before and after entering and leaving the chambers for their content of SO_2 and the proportion of this gas to the other ingredients thus regulated.	Process for determining the amount of SO_2 in chamber gases in order to regulate same.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 284

Contribution from the Office of Public Roads and Rural Engineering, LOGAN WALLER PAGE, Director

Washington, D. C. September 17, 1915

CONSTRUCTION AND MAINTENANCE OF ROADS AND BRIDGES FROM JULY 1, 1913, to DECEMBER 31, 1914.

CONTENTS.

INTRODUCTION.

Owing to the fact that the active field work of the office accords better with the calendar year than with the fiscal year, it has been thought best to report herein the work of the Divisions of Construction, Maintenance, and National Park and Forest Roads for the past 18 months, and in the future to have the reports cover the calendar years. This bulletin takes up the field work of the above three divisions where Department Bulletin No. 53 (Object Lesson and Experimental Roads, and Bridge Construction, 1912–13) left off. These three divisions have been formed from the one division of engineering since Bulletin 53 was issued, and the records of work divided accordingly.

As mentioned in Bulletin No. 53, the Office of Public Roads and Rural Engineering is empowered by a provision of the agricultural act to expend a portion of its appropriation " for investigations of the best methods of road making and the best kinds of road-making materials, and for furnishing expert advice on road building and maintenance."[1] In the interpretation of this clause the desire of the office has been to demonstrate in a practical way the need for good roads, as well as the benefits derived from them, and at the same time to

[1] Agricultural act, 1914, Public No. 430, 62d Cong., 3d sess., approved Mar. 4, 1913.

show to the various communities the best and most economical methods of road and bridge construction and maintenance.

The work consists in furnishing upon the request of the local officials the services of one or more engineers to make surveys, estimates, and specifications for road improvements, and to supervise the construction, in addition to giving practical advice to the local authorities, who must furnish all machinery, materials, and labor.

WORK OF THE DIVISION OF CONSTRUCTION.

The work of the Division of Construction, of which Vernon M. Peirce is chief, comprises the following projects: Construction of object-lesson roads, construction of experimental roads, construction of post roads, superintendence of county roads, design and inspection of bridges and culverts.

OBJECT-LESSON ROADS.

Short stretches of various kinds of roads in different communities have been constructed, upon application from local road authorities, as object lessons, for the purpose of demonstrating the proper materials and methods of construction in the respective communities. Forty object-lesson roads have been built during the period from July 1, 1913, to December 31, 1914. A detailed account of each one follows, given in order of the type of construction, the more expensive forms first. Under these types the roads are given alphabetically by States, counties, and towns.

CEMENT-CONCRETE ROAD.

Prince Edward County, Farmville, Va.—Work was begun on a cement-concrete road extending from Farmville toward Hampden Sidney on September 25, 1913, and completed October 18, 1913, with a loss of one day on account of rain. The surrounding land is rolling and the soil a red clay. The road was graded 24 feet wide in both cuts and fills for a distance of 1,450 feet. The earth was loosened with plows and hauled with slip scrapers, wheel scrapers, and wagons. A steam roller was used on the subgrade. The road was surfaced with concrete 16 feet wide for a distance of 515 feet, making an area of 916 square yards. The thickness is 7 inches at the middle and 5 inches at the sides. The mixture used was 1 part cement, 2 sand, and 4 gravel. Expansion joints of two strips of two-ply tar paper were placed every 25 feet.

One 18-inch 28-foot corrugated-iron pipe culvert was placed at a cost of $32. The total cost of the work, excluding the pipe culvert, was $1,413.13, or $1.137 per square yard. Labor was $1.50 per day and teams $4 per day of 10 hours. The principal items of cost were: Excavation and embankment, $537.40; rent of roller, five days, at $5 per day, $25; 3 tons of coal, at $4.35 per ton, $13.05; cement, 170 barrels, at $1.83 per barrel, $311.10; sand, 50 cubic yards, at $0.10 per cubic yard, $5; loading and hauling sand to road, $0.66 per cubic yard, $33; gravel, f. o. b. cars at siding, 125 tons, at $1.60 per ton, $200; loading and hauling gravel, 1½ miles, $0.379 per ton, $47.38; rent of concrete mixer, six days, at $4 per day, $24; coal for mixer, 2 tons, at $4.35 per ton, $8.70; mixing and placing concrete, at $0.199 per square yard, $182.37; setting forms, $15.63; and miscellaneous labor, $10.50.

BITUMINOUS-MACADAM ROADS.

DADE COUNTY, LEMON CITY, FLA.—Work was conducted on an experimental object-lesson road beginning about one-fourth mile north of Lemon City, on the Biscayne Drive, during January and February, 1914. The work consisted of the construction of five sections of bituminous-macadam road; the stone was a local coralline rock, with various bituminous materials for the top coat. The surfaced width was 18 feet and the length 334.4 feet, making a total area of 668.8 square yards.

The total cost of the work was $420.77, or $0.629 per square yard.

Detailed description will be found in Progress Report of Dust Prevention and Road Preservation for 1914.[1]

PALM BEACH COUNTY, WEST PALM BEACH, FLA.—Work was conducted on an experimental object-lesson road beginning at a point about 2 miles south of West Palm Beach, on the Miami-Quebec Highway, during April, 1914. The work consisted of the construction of seven sections of bituminous-macadam road. The stone was a local coralline rock, with various bituminous materials for the top coat. The surfaced width was 15 feet and the length 860 feet, making a total area of 1,433 square yards.

The total cost of the work was $808.17, or $0.564 per square yard.

A detailed description will be found in Progress Report of Dust Prevention and Road Preservation, 1914.[1]

AUGUSTA COUNTY, STAUNTON, VA.—Work was begun on a road leading from Staunton toward Middlebrook on September 16, 1913. This office furnished a representative for the purpose of instructing the local authorities in applying the bituminous surface. He superintended the laying of one kind of bituminous material and turned this one section over to the local authorities on September 29, 1913, with 2½ days lost due to bad weather.

When the office representative arrived this road had been graded 21 feet wide in both cuts and fills for a length of 1,700 feet. The subgrade, 15 feet wide, had been prepared, the shaping was practically done, and most of the first course of rock had been placed.

The adjacent land is rolling and the natural soil is clay and rock. The crushed rock was a limestone with good binding qualities and a fair wearing quality. It was loaded into wagons by gravity from the bins, hauled about three-quarters of a mile, and dumped on the road in piles and spread with rakes and shovels.

On the prepared subgrade the No. 1 stone, ranging from 2 to 3½ inches in size, had been spread to a depth of 5 inches and rolled until compacted to 3½ inches. On this course was spread 3 inches of loose No. 2 stone, ranging from three-fourths inch to 2 inches in size, and rolled until compacted to 2 inches. The bituminous binder was spread on this course at the rate of 1½ gallons to the square yard. This was covered with screenings varying from one-fourth to three-fourths inch in size. The road was then rolled, and a seal coat of about one-half gallon of bituminous binder applied. The binder was delivered in a tank car and heated by steam from a pump station of the Chesapeake & Ohio Railroad. At the time of the departure of the office representative 2,106

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[1] Bulletin No. 257, U. S. Dept. of Agriculture.

square yards of bituminous surfacing was entirely completed, 270 tons of No. 2 stone and 63.83 tons of screenings had been spread, and 5,338 gallons of bitumen used.

The equipment consisted of a 10-ton roller, a 700-gallon distributor wagon, rattan brooms, etc. State convicts were employed as laborers. Their labor was valued at $1 per day of 10 hours. The teams were hired at $3 per day; roller at $5 per day; roller man at $2 per day; night watchman and subforeman at $2 per day.

The cost of the bituminous surface, including No. 2 stone and screenings, was $1,069.44, or at the rate of $0.507 per square yard. The principal items of cost were as follows: Trimming shoulders, $0.80; stone in the bins at $1 per cubic yard, $333.83; hauling stone to road at $0.178 per cubic yard, $59.40; spreading No. 2 stone at $0.075 per cubic yard, $20.40; spreading screenings at $0.218 per cubic yard, $13.90; rolling, including labor, rent, and fuel, at $0.007 per square yard, $22.05; general expenses, $7.50; demurrage on tank car, $11; bituminous material at $0.09 per gallon, $480.42; unloading and hauling same at $0.0025, $13.40; heating bitumen, including depreciation of equipment, $62.04; spreading bitumen, $27.50; sweeping surface, $3.60; patching, $0.60; cost of steam, $13.

BITUMINOUS RESURFACING.

LEE COUNTY, FORT MYERS, FLA.—Work was begun resurfacing the McGregor Boulevard leading from Fort Myers toward Punta Rassa on April 29, 1914, and completed May 7, 1914. The road was built with shell and given a bituminous surface treatment in the fall of 1912 under the supervision of this office.[1] From the time of the construction in 1912 to the resurfacing in May, 1914, the road was practically without maintenance or repair.

The surface was prepared by sweeping it clean with a street sweeper and hand brooms, and the grass was scraped from the roadsides with a grader. The oil was hauled an average of 2¼ miles and applied from a 500-gallon gravity distributor to the hard, dry, clean surface. It was allowed to stand until absorbed, and then covered with a thin coat of sand. One-half of the road was treated at a time in order to allow traffic the uninterrupted use of the road. The average rate of application was 0.246 gallon per square yard. The sand, obtained from the roadside, was screened, and spread to a depth of about three-sixteenths of an inch.

The road was treated for a width of 16 feet and a length of 8,950 feet, or an area of 15,911 square yards. Labor was $1.80 per day, and teams $5 per day of nine hours. Oil cost $0.0575 per gallon f. o. b. tank cars at Fort Myers. The total cost of the work was $478.51, which is at the rate of $282 per mile, or $0.0301 per square yard. The principal items of cost were preparing surface, $0.0029 per square yard; cost of oil, $0.0142 per square yard; hauling and applying, $0.0013 per square yard; brooming, $0.0018 per square yard; excavating and screening sand, $0.0088 per square yard; and spreading sand, $0.0011 per square yard.

MACADAM ROADS.

FAUQUIER COUNTY, RECTORTOWN, VA.—Work was begun July 7, 1913, on a macadam road extending from the depot at Rectortown north to Marshall Road, and completed November 1, 1913, with a loss of 41 days on account of bad weather. The adjacent land is rolling and the natural soil is clay from station

[1] Described in Bul. No. 53, U. S. Dept. of Agriculture, "Object-lesson and Experimental Roads and Bridge Construction, 1912–13."

0+00 to 27+00 and solid rock from station 27+00 to 28+00. The road was graded 26 feet wide in cuts and 20 feet wide in fills for 2,800 feet. The maximum cut was 1.7 feet, the maximum fill 2.6 feet. The total amount of excavation was 1,336 cubic yards, of which 131 cubic yards was rock excavation. The maximum grade of 8 per cent was reduced to 5.8 per cent.

Earth was loosened with plows and picks, loaded with shovels, hauled with wagons and wheelbarrows, and spread with shovels. A surface of macadam was laid for 2,800 feet, 14 feet wide, making 4,355 square yards. The macadam was applied in two courses, the first-course stones ranging in size from 1½ to 3 inches and applied 5½ inches deep; the second course ranging in size from three-fourths inch to 1½ inches and applied 2½ inches deep. On this course the screenings were applied, ranging in size from dust to one-half inch. When compacted the surfacing was 6 inches in depth. The material used for surfacing was a diabase, locally known as "ironstone." It has fair binding qualities and good wearing qualities. The crusher was set up at station 10+50 and the haul from the quarry was about 50 feet; the haul of water for the crusher engine was 2,600 feet and the average haul of water for the sprinkler was 3,000 feet. Stone was brought to the crusher in wagons and wheelbarrows, crushed, stored in bins, and loaded from the bins directly into the wagons by means of a chute.

Drainage structures were constructed as follows: At 0+12 a 15-inch corrugated-iron pipe; at 9+80 a 12-inch corrugated-iron pipe; at 12+20 a 12-inch corrugated-iron pipe; at 19+00 a 3 by 6 foot concrete culvert; at 23+50 a 12-inch corrugated-iron pipe; and at 25+80 a 12-inch corrugated-iron pipe. Concrete head walls were built at all pipe ends.

The equipment consisted of a 10-ton roller, a 12-horsepower engine, and a No. 4 rock crusher.

Labor cost from $1.25 to $2.25 per day of 10 hours, and teams cost from $3 to $5. The total cost of the road was $4,215.69, which is at the rate of $0.968 per square yard. The principal items of cost were as follows: Clearing and grubbing, $23.73; excavation at $0.623 per cubic yard, $833.88; shaping at $0.02 per square yard, $90.43; culvert pipe, $103.45; labor on same, $47.30; concrete culvert, $31.55; labor on same, $76; end walls, $5.50; side walls, $208.55; excavation for culvert, $22.77; forms, $39.28; quarrying at $0.934 per cubic yard, $600.47; hauling to crusher at $0.837 per cubic yard, $347.60; crushing at $0.495 per cubic yard, $524.86; hauling, crusher to road, at $0.203 per cubic yard, $212.60; spreading at $0.106 per cubic yard, $111.51; sprinkling at $0.0066 per square yard, $32.50; rolling at $0.055 per square yard, $242.80; general expense, $162.30; trimming shoulders, $5.87; explosives, $106.67; blacksmithing, $68.11; reinforcing steel, $34.21; lumber, $25; cement, $65.50; extras, $16.61; fuel. $176.64.

CHERT MACADAM ROAD.

NEWTON COUNTY, NEOSHO, MO.—Work on a road extending from Neosho southward toward Pineville was begun November 28, 1913, and completed December 19, 1913, with a loss of 4½ days on account of bad weather. The adjacent land is hilly and the natural soil is chert and clay. For a distance of 2,000 feet the road was graded to a width of 26 feet in cuts and to a width of 22 feet in fills, for which 2,270 cubic yards of material was moved. The maximum grade was reduced from 9 per cent to 6 per cent. The material was loosened with plows and a heavy harrow, hauled in wheel scrapers, and spread with shovels. The average haul was 300 feet, with a maximum haul of 500 feet.

The surface material was a chert varying in size from dust to 2½ inches. The run of the crusher was used without screening and the material was spread in one course to a depth of 6 inches for a width of 8 feet and a length of 933 feet, making 829 square yards. About 138 cubic yards of material were used with an average haul from the crusher to the road of 630 feet. Planks 2 by 6 inches were used at the sides to secure a uniform depth of 6 inches, and against these planks shoulders were built. The surfacing material was loaded into wagons direct from the elevator, hauled in farm wagons and spread with shovels, and the surface given a crown of three-fourths inch to the foot.

The equipment consisted of fourteen wheel scrapers, four drag scrapers, two heavy grading plows, one heavy harrow, one rooter, one road grader, one 6-ton horse roller, one crusher, one 25-horsepower traction engine.

Labor cost, $1.80, and teams, $3.60 per 9-hour day. The contract for the engine at $10 per day included fuel. The total cost of the road was $1,190.43, which is at the rate of $0.222 per square yard of graded area. The principal items of cost were as follows: Plowing, at $0.14 per cubic yard, $315.02; scraping, at $0.2685 per cubic yard, $609.60; trimming banks, at $0.0322 per square yard, $38.70; blasting, at $0.6867 per cubic yard, $20.60, including $8 for dynamite; hand-breaking stone, at $1.282 per cubic yard, $42.30; trimming shoulders, at $0.028 per linear foot, $26.43; spreading stone, at $0.0587 per cubic yard, $8.10; crushing, at $0.5155 per cubic yard, $54.13; rolling, at $0.0052 per square yard, $20.80; hauling stone to crusher, varying from $0.25 to $0.30 per cubic yard, $33.35; hauling crushed stone to road, at $0.2038 per cubic yard, $21.40.

GRAVEL ROADS.

Coahoma County, Clarksdale, Miss. (Section 1).—A gravel road leading from Clarksdale northwesterly toward Friar Point was begun on January 5, 1914, and completed January 19, 1914, with a loss of four days waiting for materials. The adjacent land is level and the natural soil a buckshot clay. A section 1,060 feet long was graded with 580 feet surfaced 20 feet wide, and 480 feet surfaced 16 feet wide, making the surfaced area 2,142 square yards. The grade of the road was not materially changed, and the average cut was but 0.5 foot with a maximum of 1 foot. The material was loosened with plows, loaded by hand into slat-bottom wagons, and hauled away. The surfacing material, which was Tishomingo gravel and novaculite, was shipped in on the cars. The gravel weighed 3,000 pounds to the cubic yard, and the novaculite weighed 2,400 to the cubic yard. The novaculite seemed to have better wearing and binding qualities than the gravel. The material was spread to a loose depth of 12 inches by means of rakes, shovels, and the drag. It was afterwards rolled with a 5-ton horse roller until the material was compacted to 8 inches. The average haul from the cars to the road was one-fourth mile. The material contained particles of stone from the size of peastone to that of cobblestone. The road was given a crown of 6 inches on the surfaced portion.

The equipment consisted of a road grader, a 5-ton horse roller, wagons, and small tools. Labor cost $1.50 and teams $4.50 per 10-hour day.

The cost of the novaculite on the cars was $1.63 per 2,000 pounds, or $1.96 per cubic yard, and the gravel $1.47½ per 2,500 pounds, or $1.77 per cubic yard. The total cost of the road to the community was $1,722.72, which is at the rate of $0.804 per square yard for the surfacing. The principal items of cost were as follows: Excavation, $71; shaping, at $0.0217 per square yard, $46.50; surfacing material, $1,191.22; loading wagons from car at $0.126 per cubic yard, $94.50; hauling from cars to road, at $0.315 per cubic yard, $236.25; spreading material, at $0.058 per cubic yard, $43.50; trimming shoulders, $16.50; rolling, at $0.011 per square yard, $23.25.

COAHOMA COUNTY, CLARKSDALE, MISS. (SECTION 2).—A second section of gravel road leading from Clarksdale northwesterly toward Friar Point was begun November 17, 1913, and completed January 29, 1914, with a loss of one day, due to bad weather. The adjacent land is slightly rolling and the soil a sandy loam throughout the entire length. A section 2,640 feet long was graded for a width of 26 feet in both cuts and fills. The gravel surface is 2,640 feet long for a width of 10 feet, making a surfaced area of 2,933 square yards. The maximum cut was 2 feet and the maximum fill 3 feet, and the material was moved with slip scrapers after being loosened with plows. The average haul was 100 feet, with a maximum haul of 600 feet. The surfacing material was Tishomingo gravel, shipped on the cars. The haul from the cars to the road was approximately 3½ miles. The material was spread by hand, using rakes and shovels. The material wears well under moderate traffic, but tends to lose its binding quality in dry weather.

The gravel was spread in one course to a depth of 9 inches and compacted to 6 inches by aid of a roller. The gravel ranged in size from that of cobblestone to peastone. It is estimated that 867 cubic yards of gravel were used.

As completed, the road has a 4-foot shoulder of earth on one side and a 12-foot earth roadway on the other, with the finished surface having a crown of 1 inch to 1 foot. One cross drain, 25 feet long, of 12-inch clay pipe was laid at station 52+00.

The equipment consisted of a road grader, a 5-ton horse roller, slat-bottom wagons, and small tools. Labor cost $1.50, and teams $4, including driver per 10-hour day. The total cost of the road to the community was $2,862.38, which is at the rate of $0.976 per square yard. The principal items of cost were as follows: Excavation, $197.98; shaping, at $0.02 per square yard, $59.60; 12-inch clay pipe, at $0.45 per linear foot, $11.25; labor on same, $3.25; foreman, $43.50; gravel, at $1.475 per cubic yard, $1,278.83; hauling from cars to road per contract, at $1.25 per cubic yard, $1,083.75; spreading gravel, at $0.12 per cubic yard, $88.35; rolling per square yard, at $0.015, $44.12; trimming shoulders and ditches, $51.75.

SUNFLOWER COUNTY, INDIANOLA, MISS.—A gravel road leading from Indianola northerly toward Faisonia was begun on October 14, 1913, and completed November 19, 1913, with a loss of nine days on account of bad weather and one day due to other causes. The adjacent land is level, with a buckshot soil the entire length of the road. A section 1,790 feet long was graded for a width of 24 feet. The gravel surface is 16 feet in width for the entire length, giving an area of 3,182 square yards. The grade of the road was not materially changed, the average fill was but 0.8 foot, and the maximum 1.83 feet. It is estimated that 1,337 cubic yards of material were used in the embankment. The maximum haul was 40 feet. The material was loosened by plows and moved with drag scrapers.

The surfacing material was shipped in by rail a distance of 243 miles, and was the pit-run of gravel with good wearing qualities, but with varying binding qualities, and the gravel required careful spreading. It was applied in one course for a depth of 10½ inches at the center and 8 inches at the sides before compacting. The crown of the road was five-eighths inch to the foot.

The equipment consisted of a 10-ton tractor roller and drag scrapers. The surfacing material, of which 997 cubic yards were used, was delivered on the cars at the contract price of $1.46 per cubic yard, making it cost $1,452.60 at the siding. Labor cost $1.50 per day, and teams, including driver, $3.50 per day, based on a 10-hour day. The total cost of the road to the community was $2,218, which is at the rate of $0.697 per square yard. The principal items of cost were as follows: Embankment, at $0.131 per cubic yard, $175.20; shaping the subgrade, at $0.005 per square yard, $19.50; gravel on siding, at $1.46 per cubic yard, $1,452.60; hauling and loading gravel, at $0.332 per cubic yard, $331; spreading gravel, at $0.035 per cubic yard, $34.95; rolling gravel, at $0.0026 per square yard, $8.25; rolling subgrade, $3.60; building shoulders, $14.25; equipping wagons, $1.05; general expenses, $111; rehandling gravel to save demurrage, $66.60.

Randolph County, Asheboro, N. C.—A gravel road leading from Asheboro north toward Randleman was begun November 14, 1913, and entirely completed December 19, 1913, with two days lost on account of bad weather and one day from other causes. The adjacent land is hilly and the natural soil yellow clay from station 0+00 to 14+00; rock and yellow clay from station 14+00 to 17+00; yellow clay and some rock from station 17+00 to 24+00. A section 2,400 feet long was graded 25 feet wide in cuts and 22 feet in fills. The gravel surface is 2,400 feet long and 10 feet in width, making an area of 2,667 square yards. Three wooden box culverts were constructed, each 1 by 1.5 feet by 24 feet long. One 4-inch tile was used for road drainage between stations 1+75 and 2+50.

The maximum grade was reduced from 8 per cent to 5 per cent. The maximum cut was 4.8 feet, and the maximum fill was 2 feet. Nine hundred and seventy-six cubic yards of earth were excavated, with an average haul of 150 feet and a maximum haul of 400 feet. In addition, about 47 cubic yards of rock were removed. This material was loosened with picks, plows, and dynamite, hauled in wagons and slip scrapers, and spread with shovels and road grader.

The surfacing material was gravel containing about 60 per cent quartzite with top soil and clay. It was hauled about 1,000 feet and spread with stone forks. The gravel appears to have good binding and wearing qualities. The gravel was applied in one course to a depth of 6 inches before compacting, and the size of the particles ranged from dust to 3 inches. Four hundred and forty-four cubic yards of gravel were used, of which 290 cubic yards were purchased. The crown of the road, as finished, was three-fourths inch to the foot.

The equipment consisted of a road grader and drag scrapers.

Labor cost $1.25 to $1.50, and teams $2.50, based on a 10-hour day. The total cost of the road to the community was $520.15, which is at the rate of $0.195 per square yard. The principal items of cost were as follows: Excavation, at $0.258 per cubic yard, $264.24; shaping, at $0.0056 per square yard, $15; culvert materials, $5.50; labor on same, $3.12; clearing and grubbing, $11.44; gravel, at $0.1034 per cubic yard, $30; loosening and loading, at $0.138 per cubic yard, $61.25; hauling from pit to road, at $0.1267 per cubic yard, $56.25; spreading gravel, at $0.0301 per cubic yard, $13.38; shaping same, at $0.0075 per cubic yard, $20; trimming shoulders, $0.0062 per linear foot, $15; general expenses, $16.25; explosives, $8.72.

Kinney County, Brackettville, Tex.—Work was begun surfacing with gravel the Spofford road, extending south from Brackettville toward Spofford, on April 23, 1914, and completed May 6, 1914, with no time lost from any cause. The adjacent land is rolling and the soil is black lime, with a small amount of chalk throughout. The road was graded 36 feet wide in both cuts and fills and was 1,500 feet in length. There was practically no excavation or fill, the earth was loosened by plows drawn by tractor and hauled and spread by two graders drawn by tractor. The maximum fill was 0.5 foot and the total excavation did not exceed 500 cubic yards. The maximum grade was 2 per cent.

A surface of gravel was laid for 1,500 feet, 16 feet wide, making 2,667 square yards. The gravel was applied in one course with a loose thickness of 8 inches at the center and 4 inches at the sides, with a crown of 6 inches. The material was dumped between 2 by 4 inch planks on edge at sides and the shoulders were built up against the edge of gravel. All the gravel used for surfacing passed a 3-inch ring, had fair binding and wearing qualities, and was obtained from a pit at an average haul to the road of three-fourths of a mile. No water was used on the road during the rolling, which was done with a 6-ton horse roller. The gravel was hauled by farm wagons of 1 cubic yard capacity and Troy dump wagons of 3½ cubic yards capacity hauled by a tractor.

The equipment consisted of one 20-horsepower gasoline tractor, two extra heavy graders, six 3½-yard wagons, a 6-ton horse roller, two rooters, two road plows, four drag scrapers, and one steel road drag. Labor cost $1.20 per day of eight hours and teams $3 per day. The total cost of the road was $460.60, which is at the rate of $0.1727 per square yard, or $1,621.31 per mile.

The principal items of cost were as follows: Plowing and grading, $0.328 per square yard of finished surface; rolling subgrade, $0.0017 per square yard; loosening and loading gravel, $0.3447 per cubic yard; hauling gravel, $0.3981 per cubic yard; spreading gravel, $0.0584 per cubic yard; rolling gravel, $0.0014 per square yard; trimming shoulders and ditches, $0.0056 per linear foot.

CALDWELL COUNTY, LOCKHART, TEX. (No. 1).—Work was begun on a gravel road extending south from Lockhart toward Seawillow on the Gonzales road May 28, 1914, and completed on August 7, 1914, with a loss of four days on account of bad weather. The adjacent land is rolling and the natural soil was as follows: *Section 1*—Station 0+00 to 7+00, black waxy; station 7+00 to 28+00, gray adobe; station 28+00 to 40+00, clay gravel; station 40+00 to 49+00, limestone, gravel, and black dirt. *Section 2*—Station 0+00 to 32+00, white adobe. The road was graded 36 feet wide in cuts and 20 feet wide in fills. The maximum cut was 1.5 feet and the maximum fill 2.5 feet. No change was made in maximum grades. Earth was loosened with plows, hauled by Fresno scrapers, and shaped with a blade grader.

A surface of gravel 14 feet wide was laid for 8,975 feet, making 13,961 square yards. The gravel was applied in two courses, the first course from 1½ to 3 inches in size and applied 6 inches loose depth; the second course from sand to 1½ inches, applied 3½ inches loose depth. When completed the surfacing was 7¾ inches deep. The material used for surfacing was a pit sand-clay gravel with good binding and wearing qualities. The average haul for both gravel and water for sprinkling was 2,000 feet. The gravel was loaded with slip scrapers through a loading trap into slat-bottom wagons and was spread with a grader.

Drainage structures were built as follows: One 18-inch by 22-foot corrugated pipe culvert; six 24-inch by 22-foot corrugated pipe culverts; three 30-inch by 22-foot corrugated pipe culverts; and one 36-inch by 8-foot culvert. Twenty-nine barrels of cement and 31 cubic yards of gravel were used in head walls.

The road equipment consisted of Fresno scrapers, road grader, slip scrapers, and slat-bottom wagons.

Labor cost $2 per day and teams $4 per day of 8 hours. The total cost of the road was $2,676.69, or $0.1770 per square yard, and at the rate of $1,453.70 per mile. The principal items of cost were as follows: Culverts complete, $667.37; clearing and grubbing, $4.80 per acre; excavation, $0.1959 per square yard; shaping subgrade, $0.0027 per square yard; concrete end walls, $5.10

per cubic yard; surfacing material in pit, $0.07 per cubic yard; loading gravel with slip scrapers through trap, $0.1571 per cubic yard; hauling gravel 2,000 feet and dumping, $0.2021 per cubic yard; spreading gravel with grader, $0.0181 per cubic yard; finishing, $0.0005 per square yard; general expenses, including superintendent, $108.

CALDWELL COUNTY, LOCKHART, TEX. (No. 2).—A second gravel object-lesson road was built at Lockhart, Tex., on the League Line Road, extending southwest from Burdett Wells Road toward Luling. Work was begun on March 5, 1914, and completed July 7, 1914, with a loss of 46 days on account of bad weather and 9 days for other causes. The adjacent land is rolling, and the soil from station 0 to 56+50 is "black waxy"; station 56+50 to 65+00, chocolate loam; and from station 65+00 to 82+00, "black waxy." The road was graded to a width of 36 feet in cuts and 20 feet in fills for a length of 9,680 feet. The maximum cut was 1.5 feet and the maximum fill was 7 feet. The maximum grade of 4 per cent was reduced to 3 per cent. Earth was loosened with plows, handled with Fresno scrapers, and shaped with a road machine.

The sand-gravel surfacing was loaded into slat-bottom wagons through a loading trap and hauled an average distance of 3,000 feet to the road, where it was spread to a width of 14 feet, making a surfaced area of 15,058 square yards. Two courses were laid, as on the Gonzales Road previously described.

Drainage structures were built as follows: Five 30-inch corrugated-iron pipe culverts 22 feet long, and two 36-inch corrugated-iron pipe culverts 22 feet long, all with concrete head walls containing a total of 26 barrels of cement and 26 cubic yards of pit-run gravel.

The road equipment used consisted of a road grader, three Fresno scrapers, six slip scrapers, and slat-bottom wagons.

Labor cost $2 per day and teams $4 per day. The total cost of the road was $3,426.52, or $0.2275 per square yard, which is at the rate of $1,868.46 per mile. The principal items of cost were: Clearing and grubbing, $16.72 per acre; excavation, $0.2625 per square yard; shaping subgrade, $0.0035 per square yard; culverts, including material and labor, $452.87; surfacing material in pits, $0.05 per cubic yard; loading, $0.1573 per cubic yard; hauling, $0.2582 per cubic yard; spreading gravel, $0.0098 per cubic yard; shaping gravel, $0.0007; right of way, $117, which is at the rate of $125 per acre; general expenses, $91.50.

COMAL COUNTY, NEW BRAUNFELS, TEX.—Work was begun on a gravel road extending southeast from New Braunfels toward Seguin on March 13, 1914, and completed May 28, 1914, with a loss of 25 days on account of bad weather. The adjacent land is rolling, and the nature of the soil is "black waxy." The road was graded 30 feet wide in both cuts and fills for a distance of 4,600 feet. A road machine was used to do all the grading, as it was light work. The maximum grade of 2.3 per cent was reduced to 1.275 per cent.

The gravel surfacing was obtained from pits, hauled an average of three-fourths of a mile, and spread to a width of 16 feet, making a surfaced area of 8,177 square yards.

One 12-inch and one 24-inch corrugated-metal pipe culvert 22 feet long were laid.

The total cost of the work was $1,786.36, or $0.218 per square yard. The principal items of cost were clearing and grubbing, $3; grading, $226.75; gravel ready for use, including stripping pits and drilling, 2,272 cubic yards, at $0.179 per cubic yard, $752.15; explosives, caps, etc., $101.40; loading and hauling 2,272 cubic yards of gravel, at $0.247 per cubic yard, $562.50; spreading gravel, at $0.033 per cubic yard, $75.06; rolling, $5; shaping, $45; and culverts, $15.50.

UVALDE COUNTY, UVALDE, TEX.—A gravel road leading from Uvalde eastward toward Sabinal was begun January 24, 1914, and abandoned February 6, 1914, for lack of funds. The adjacent land is rolling, with brown clay from station 0+00 to station 22+00; soft rock from station 22+00 to station 35+00; black clay loam from station 35+00 to station 57+00. A section 4,300 feet long was graded for a width of 32 feet in both cuts and fills. The gravel surface is 2,200 feet long and 16 feet wide, making a surfaced area of 3,911 square yards. One timber bridge having a 15-foot span was constructed at station 42+00.

The maximum grade was reduced from 6.4 per cent to 4.2 per cent, the maximum cut was 2.8 feet, and the maximum fill 2.9 feet. Approximately 652 cubic yards of gravel were used, spread 10 inches deep at the center, and feathered to 0 at the edges. The gravel was spread 16 feet wide and finished with a crown of 1 inch to the foot.

Labor cost $1.50 and county teams $1 per 8-hour day. The total cost of the road to the community was $622.13, which is at the rate of $0.159 per square yard for the surfacing. The principal items of cost were as follows: Excavation, $94.25; loosening and loading gravel, $8.50; hauling gravel, $305.60; spreading gravel, $36; finishing, $16.25; bridge excavation, $33.75; lumber, $86.78; labor on bridges, $41.

SAND-CLAY ROADS.

DUKES COUNTY, TISBURY, MARTHAS VINEYARD, MASS.—During the month of August, 1913, a section of the Makonikey Road in the town of Tisbury, originally very sandy, was surfaced 16 feet wide with natural sand clay or top soil to a uniform loose depth of 9 inches. This was compacted partly by the traffic and partly by means of a light stone roller and the drag. The length of the section was 320 feet, making 569 square yards, and the total cost was $75.38, which is at the rate of $0.132 per square yard.

Two-wheeled dump wagons were used for hauling the top soil, and the average load was 24 cubic feet. The average haul was 2,850 feet.

Another section of object-lesson road was constructed on the crossroad from Chilmark Post Office to Menemsha Creek by surfacing with a sand-clay mixture. After shaping the subgrade clay was hauled and spread to a width of 16 feet and a uniform loose depth of 8 inches, then covered with sand to a depth of 4 or 5 inches. The material was thoroughly cut up by plowing and disk harrowing, then by a spiked-tooth harrow followed by disking and shaping with a plank drag. The road was at this time in a loose and powdery condition, but mechanically well mixed. It rained shortly after the completion of this part of the work, and the section was then rolled and dragged, with excellent results.

The total length of this section was 180 feet, making 320 square yards, and the total cost $89.75, which is at the rate of $0.280 per square yard. The price could be reduced one-third if a greater length were built, with a better organized working force.

DUKES COUNTY, GAY HEAD, MASS.—The improvement of the State Road, extending west from Chilmark toward Gay Head Light, was begun on December 3, 1913, and completed on June 8, 1914, after a loss of 12½ days on account of bad weather and 101 days, from January 11 to April 21, 1914, when work was discontinued during the winter. The adjacent land is rolling and composed of successive stretches of sandy loam, fine sand, clay, and a natural sand-clay mixture.

A section 11,600 feet in length was graded 22 feet wide in both cuts and fills. The maximum cut was 3 feet and the maximum fill 4 feet. The road was surfaced 16 feet wide with a sand-clay mixture, making 20,622 square yards. Where the subgrade was sand, clay was added, and vice versa. The surfacing was laid about 6 inches in depth. For several short stretches the natural soil was a sand-clay mixture and required no other surfacing material.

The drainage structures were: Twelve vitrified-clay pipes, ranging in size from 8 to 15 inches in diameter and totaling 342 feet in length, and 1 blind stone drain 2 feet wide, 2 feet deep, and 100 feet in length.

The total cost of the work was $3,506. Labor cost $2 per day and teams $5 per day of 9 hours. The principal items of cost were: Excavation (earth), 2,651 cubic yards at $0.45 per cubic yard, $1,193.28; excavation (rock), 22 cubic yards at $1.25 per cubic yard, $27.55; trimming shoulders and ditches, $69.23; and superintendence, $90—making a total cost of grading of $1,380.06. Stripping for sand, $9.22; stripping for clay, $31.64; loading and hauling sand, 1,700 cubic yards at $0.223 per cubic yard, $378.39; loading and hauling clay, 2,300 cubic yards at $0.344 per cubic yard, $791.76; spreading sand and clay, 24,350 square yards at $0.003 per square yard, $73.70; mixing 20,622 square yards of sand and clay at $0.010 per square yard, $199.52; shaping and crowning 20,622 square yards at $0.004 per square yard, $90.57; superintendence, $118.46; and 1,050 cubic yards of clay at $0.08 per cubic yard, $84—making a total cost of surfacing $1,777.26, or $0.090 per square yard. Miscellaneous labor cost $83.46; excavation for pipe culverts, $34.72; hauling materials, $5.08; placing pipe and backfilling, $24.02; 32 linear feet of 15-inch vitrified-clay pipe at $1 per foot, $32; 234 linear feet of 12-inch vitrified-clay pipe at $0.60 per foot, $140.40; 28 linear feet of 10-inch vitrified-clay pipe at $0.40 per foot, $11.20; and 48 linear feet of 8-inch vitrified-clay pipe at $0.30 per foot, $14.40; cement, $340—making a total of $265.22 for 342 linear feet of vitrified-clay pipe in place, or $0.775 per linear foot.

Northampton County, Jackson, N. C.—Work was started on the Church Street Extension Road, which leads north from Jackson toward Seaboard, on September 4, 1913, and was completed on November 3, 1913. Seven days were lost on account of bad weather and one day from other causes. The weather and labor conditions added materially to the cost of the work. The land adjacent to the road is comparatively level and the soil is yellow clay mixed with fine sand.

The improvement consisted in grading and shaping the existing road and surfacing it with a sand-clay mixture that contained about 25 per cent of gravel. The soil was loosened with plows and picks, hauled in drag scrapers, and spread by the scrapers and grader. The maximum cut was 1.1 feet and the maximum fill 1.3 feet. The maximum grade was reduced from 3.3 to 1.7 per cent.

One corrugated-iron pipe, 24 inches in diameter and 26 feet long, was laid, and two corrugated-iron pipes were laid at driveways, both 20 feet long and 12 and 15 inches, respectively, in diameter. Head walls of concrete were placed at the ends of the largest pipe.

Surfacing material was hauled about 1 mile and consisted of about 50 per cent sand, 25 per cent clay, and 25 per cent gravel. It was hauled in dump wagons and spread by hand labor and by the road drag. When compacted the material was 7 inches at the center and 4 inches at the sides, with a width of 14 feet surfaced. The crown of the road was four-sevenths inch to the foot.

The road was graded to a length of 2,500 feet, with a width of 30 feet in both cuts and fills, and surfaced for 2,400 feet to an average width of 14 feet, making the surfaced area 3,733 square yards. Earth to the amount of 680 cubic yards was moved in excavation and 890 cubic yards of surfacing material was used.

The equipment consisted of one reversible road grader, three Twentieth Century road drags, one dump wagon, seven drag scrapers, one turning plow, one hardpan plow, one 3½-ton horse roller. Labor cost $1.25 per 10-hour day.

The total cost of the road to the community was $1,193.22, which is at the rate of $0.32 per square yard. The principal items of cost were: Excavation, 680 cubic yards, at $0.30 per cubic yard, $205.18; shaping subgrade, at $0.002 per square yard, $10; culvert pipe delivered, at $1.69 per linear foot, $44; labor on the same, $0.44 per linear foot, $9.10; drain pipe at driveways, $0.94 per linear foot, $37.75; labor on the same, $0.20 per linear foot, $8.10; labor on end walls, $1.71; excavation on end walls, $10.80; surfacing material, 890 cubic yards, at $0.005 per cubic yard, $4.45; loading the same, $0.26 per cubic yard, $235.25; hauling the same, $0.58 per cubic yard, $517.64; spreading the same, $0.077 per cubic yard, $68.25; rolling the same, $1.97; dragging road, $0.002 per square yard, $6.33; stripping pit, $25.90; cement, $3.09 per barrel, $4.63; sand for concrete, $1.67 per cubic yard, $0.72; gravel for concrete, $1.67 per cubic yard, $1.44.

BURKE COUNTY, MORGANTON, N. C.—Work was begun on a sand-clay road leading from Morganton to Lenoir on May 19, 1913, and completed on July 26, 1913, with a loss of one day on account of bad weather and one day from other causes. The adjacent land is hilly and the soil is red clay from station 0+00 to 5+50; a red micaceous clay from station 5+50 to 15+50; a red clay from station 15+50 to 22+00; a micaceous clay from station 22+00 to 26+00; a gray top soil over red clay from station 26+00 to 42+00; and micaceous clay from station 42+00 to 57+00. A total length of 5,700 feet was graded 25 feet wide in cuts and 22.5 feet wide in fills.

Earth was excavated to the amount of 8,960 cubic yards, with an average haul of 100 feet and a maximum haul of 700 feet. In addition, about 15 cubic yards of rock were removed. The road was surfaced 20 feet wide for 1,400 feet, making 3,111 square yards. On the graded road was placed 9 inches of sand at the center and 6 inches at the sides, and over this a course of clay 3 inches thick at the center and 2 inches thick at the sides was spread. The two materials were then mixed by means of a disk harrow.

Sixteen pipe culverts, varying in size from 12 to 24 inches, were constructed, and the ends protected with masonry head walls.

The equipment consisted of a road grader, four wheel scrapers, seven slip scrapers, one rooter plow, one road plow, and one disk harrow. The total cost of the road was $1,555.95, including culverts, or at the rate of $0.0991 per square yard. The principal items of cost were as follows: Excavation, at $0.0879 per cubic yard, $787.90; shaping, at $0.0069 per square yard, $87; culvert pipes, $223.25; labor on the same, $73.80; loading sand, $0.021 per cubic yard, $13.80; hauling sand, $0.084 per cubic yard, $54.37; loading clay, $0.021 per cubic yard, $4.50; hauling clay, $0.121 per cubic yard, $26.12; spreading, mixing, and finishing, $28.01; clearing and grubbing, $96.80; moving fence, $15.90; sidehill ditches, $9.50; general expenses, $135. Labor cost is based on $1, and teams at $2.50 per day of 10 hours. A bond issue of $50,000 is available to continue this work.

EDGECOMBE COUNTY, TARBORO, N. C.—Work was begun on a sand-clay road extending from Tarboro southward toward Conetoe on October 21, 1913, and completed December 20, 1913. The adjacent land is level, and the natural soil from station 24+54 to 50+00, sandy with a clay subsoil; 50+00 to 66+00, black sand; 66+00 to 156+54, sand. A length of 13,200 feet was graded 22 feet wide in both cuts and fills. Earth was excavated to the amount of 4,236 cubic yards, and the average haul was 325 feet, with a maximum haul of 1,800 feet.

Throughout its entire length the road was surfaced to a width of 18 feet, making 26,400 square yards. Clay was spread to a uniform depth of 6 inches, and 2,815 cubic yards of clay were hauled on the road. The material is inferior, but is an improvement over the previous sandy condition. A temporary wooden bridge was built at station 50+22, to be replaced later with a concrete bridge if present plans are carried out.

The equipment consisted of two graders, two plows, three harrows, wheel scraper, horse roller, and wagons. The total cost of the road was $1,867.55, which is at the rate of $0.0578 per square yard. The principal items of cost were as follows: Clearing and grubbing at $0.0217 per square yard, $167.90; excavation at $0.1174 per cubic yard, $497.40; shaping at $0.0018 per square yard, $48.30; loading and hauling clay at $0.2548 per cubic yard, $717.35; spreading clay at $0.0178 per cubic yard, $50.10; rolling at $0.00099 per square yard, $26.35; trimming shoulders and ditches, $88.90; stripping for clay at $0.012 per square yard, $6.60; mixing at $0.0024 per square yard, $63.90; finishing surface at $0.00215 per square yard, $57.60; general expenses, $19.75; temporary bridge, $10.40; livery, $78; survey, $35. The above costs are based upon a cost of $0.80 for labor and $0.80 per mule for an eight-hour day.

JONES COUNTY, TRENTON, N. C.—Work was begun on Main Street extending west from Trenton on September 6, 1913, and operations continued to October 3, 1913, when scarcity of labor prevented further progress. One day was lost on account of bad weather, and the inadequate force and bad weather also involved many delays and were largely responsible for the high cost of the work. The adjacent land is level and the soil sandy loam throughout.

The improvement consisted in grading and shaping the existing road and surfacing it with a sand-clay mixture. The road was entirely graded to a length of 3,600 feet, with a width varying from 40 to 46 feet in both cuts and fills. A portion of the road was partly graded for 7,200 feet. Part of the subgrade was prepared 15 feet in width and part 30 feet in width. This was surfaced to the extent of 3,680 square yards when the work was shut down.

The soil was loosened with plows and mattock, hauled with drag scoops, and spread with shovels and rakes. Clay to the amount of 409 cubic yards and 511 cubic yards of sand were hauled for surfacing. As the near-by material was unfit for use the clay was hauled a distance of 5,750 feet. It was spread to a depth of 4 inches on the road, and then covered with the sand, which was obtained from Trent River. The two materials were mixed by means of a plow and harrow. The road was shaped so that the crown of the finished surface was 1 inch to 1 foot.

Cross drains 30 feet long were constructed of 24-inch corrugated-iron pipe at stations 34+50 and 46+60.

The equipment consisted of plows, harrows, drags, scoops, and plank drag.

Labor cost $1 to $1.25 and teams $2 per 10-hour day.

The total cost of the road to the community was $795.11, and the cost of the completed section was $465.48, which is at the rate of $0.1265 per square yard for the finished surface. The principal items of cost were: Rough grading, at $0.009 per square yard, $80.50; stripping clay pit, at $0.077 per cubic yard, $31.50; loosening and loading clay, at $0.119 per cubic yard, $49; hauling, at $0.387 per cubic yard, $158.45; spreading, at $0.023 per cubic yard, $9.50; loading sand, at $0.034 per cubic yard, $17.50; hauling, at $0.155 per cubic yard, $79.48; spreading, at $0.015 per cubic yard, $7.25; mixing and dragging, at $0.009 per square yard, $32.30.

DUPLIN COUNTY, WALLACE, N. C. (SECTION 1).—Two sections of sand-clay road were constructed in the vicinity of Wallace. Work was begun on the first section, extending northeasterly from Wallace toward Chinquapin, on September 4, 1913, and completed on September 12, 1913, with a loss of one day on account of bad weather. The adjacent land is slightly rolling, with a sandy soil over a clay strata. The total length of 2,000 feet was graded 22 feet wide in both cuts and fills, but the grade of the road was not materially changed. The average haul was 50 feet, and the hauling was done chiefly with drag scrapers.

The road was plowed to bring the clay up into the sand, and the two materials were then thoroughly mixed by means of harrows and scrapers. The finishing was done with the split-log drag. The entire length of 2,000 feet was thus treated for the full width of 22 feet.

The equipment consisted of a road scraper, a disk harrow, tooth harrow, scoops, turning plow, rooter plow, horse roller, and split-log drags.

The total cost of the road was $140.25, which is at the rate of $0.029 per square yard. The principal items of cost were as follows: Clearing and grubbing, $50.66; excavation, $22.54; mixing, $22.75; shaping, $23.60; trimming the shoulders, $15.10; explosives, $5.60. The above costs are based on a labor cost of $1.25 per day of 10 hours and a cost of $0.50 per day for each mule, not including the driver.

DUPLIN COUNTY, WALLACE, N. C. (SECTION 2).—Work was begun on the second section, extending from Island Creek Bridge toward Chinquapin, on September 12, 1913, and completed on October 4, 1913, with a loss of two days on account of bad weather. The adjacent land is slightly rolling and the natural soil is mostly sand. A total length of 3,100 feet was graded 22 feet wide in both cuts and fills. The excavation amounted to 850 cubic yards and the average haul was less than 100 feet. Drag scrapers were used.

Throughout its entire length the road was surfaced to a width of 15 feet, making 5,167 square yards. The sand-clay surface was constructed by spreading the clay on the sand surface to a depth of 8 inches at the center and 6 inches at the sides. Sand was added from the slopes and gutters, and in addition to the daily use of the harrow the heavy teaming assisted in mixing the materials. The surface was finished with the split-log drag. It is estimated that about 717 cubic yards of clay were hauled to the road from the two clay pits. The binding qualities of the clay and the wearing qualities of the clay and sand appear to be very good. Five vitrified-pipe culverts were constructed, ranging in size from 10 inches to 24 inches.

The equipment consisted of a road scraper, disk and tooth harrows, log drag, plows, etc. The total cost of the road was $452.76, which is at the rate of $0.081 per square yard, exclusive of drainage structures. The principal items of cost were as follows: Grading, $182.08; explosives, $4.80; culvert materials, $27.26; labor on the same, $8.97; surfacing, $210.98; general expenses, $18.67. The above costs are based on a labor cost of $1.25 per 10-hour day and a cost of $0.50 per mule each day.

OKMULGEE COUNTY, OKMULGEE, OKLA.—Work was begun on a stretch of the road leading south from Okmulgee toward Henryetta on June 26, 1913, and completed in about 30 days. The adjacent land is slightly rolling. The soil is generally either sand or clay, with a small amount of prairie soil. The sand occurs for the most part in the depressions, while the clay occurs on the hills.

The road was graded and surfaced 20 feet wide for a distance of 5,600 feet, or an area of 12,444 square yards. The total amount of excavation was 2,990 cubic yards and the average haul was 700 feet. The sand and clay taken from the cuts was distributed so as to obtain the correct proportion for the surfacing. Equipment used consisted of plows for loosening the earth, Fresnos for short haul, and wheeled scrapers for long haul.

The grading and surfacing was done by a railroad contractor on a labor contract. The agreed scale of wages was: Foreman, $3; timekeeper, $1; men, $2; and teams with drivers, $5 per day. The total cost was $2,045.75, or $0.164 per square yard.

Beckham County, Sayre, Okla.—Work was started on the Sayre-Delhi road, which leads south from Sayre toward Delhi, on January 28, 1914, and completed February 11, 1914, with a loss of one day due to bad weather. The land adjacent to the road is rolling and the natural soil a deep sand. No material change was made in the grade. In constructing the road deep plowing was employed to loosen the roots of the dwarf oaks and a harrow was used to collect the roots, which were thrown out by hand. The sand was then graded, and on the sand bed 1,383 cubic yards of clay were spread to a depth of 8 inches before compacting. The average haul for the clay was 7,500 feet. The clay was dumped from wagons and spread by hand. It was smoothed by the use of a drag and appears to have good wearing and binding qualities. Due to the weather and high winds, the sand and clay were not mixed, but instructions were left with the local officials as to the proper manner of mixing during wet weather.

The total length graded was 4,000 feet for a width of 28 feet in both cuts and fills. The surfaced portion was 4,000 feet in length for a width of 14 feet, making 6,222 square yards surfaced. Two inches of sand were spread over the clay in order to retain the moisture.

The cost of the road to the community was $1,262.60, which is at the rate of $0.203 per square yard. The principal items of cost were as follows: Clearing and grubbing at $0.0077 per square yard, $95.80; shaping subgrade at $0.0096 per square yard, $59.50; plowing clay at $0.017 per cubic yard, $18; loading clay at $0.087 per cubic yard, $119.80; hauling clay at $0.48 per cubic yard, $663; dumping and spreading clay at $0.072 per cubic yard, $99.25; covering clay with sand at $0.007 per square yard, $45.20; preparing pit and roadway for hauling clay, $162.05. Labor cost $1.60 and teams $3 per 8-hour day.

Anderson County, Anderson, S. C.—Work was begun on a sand-clay road extending from Anderson City line westward on September 10, 1913, and completed November 14, 1913, with a loss of 10 days on account of bad weather. The adjacent land is hilly, and the natural soil a clay containing some sand. A total length of 2,300 feet was graded 32 feet wide in both cuts and fills. Earth was excavated to the amount of 2,446 cubic yards, and the average haul was 500 feet, with a maximum haul of 1,300 feet. From station 1+50 to station 4+00 a course of cinders 12 inches deep and 16 feet wide was laid as a foundation. Throughout its entire length the road was surfaced to a width of 16 feet, making 4,089 square yards. Six hundred and eighty-one cubic yards of surfacing material were used.

Cross drains were constructed as follows: From 0+50 to 1+05 a 15-inch clay pipe was laid parallel to the road, and at 21+25 the existing 15-inch clay pipe was extended 17½ feet.

The equipment consisted of a rooter plow, horse roller, grader, and wagon. The total cost of the road was $913, which is $0.1116 per square yard. The principal items of cost were as follows: Excavation at $0.23 per cubic yard, $562.86; shaping at $0.0044 per square yard, $18; labor on culverts, $11.50; end walls, $2.75; loading and hauling sand at $0.2469 per cubic yard, $169.10; spreading sand at $0.0284 per cubic yard, $19.32; rolling at $0.0007 per square yard, $2.75; loading, hauling, and spreading cinders at $0.5908 per cubic yard, $87.43; loading and hauling stone, $4.80; ditching, $14.69; mixing sand and clay, $9.90; general expenses, $6.30; cement, $3.60. The above costs are based upon a labor cost of $1 and a cost for teams of $3 per day of 10 hours.

Bee County, Beeville, Tex.—Work was begun on an adobe and sand-clay road extending west from Beeville toward Oakville on March 17, 1914, and completed on April 20, 1914, with a loss of one day on account of rain. The surrounding country is rolling and hilly. The nature of the soil is as follows: Station 0+00 to station 4+00, sandy; 4+00 to 6+00, adobe rock; 6+00 to 17+50, sandy loam; 17+50 to 20+00, adobe rock; 20+00 to 22+00, sandy; 22+00 to 27+00, adobe; 27+00 to 40+00, sandy loam underlaid with red sand-clay; 40+00 to 52+80, adobe rock. The road was graded 22 feet wide in cuts and fills for a distance of 5,280 feet. The maximum grade on the old road of 5.5 per cent was reduced to 4.5 per cent. For 4,280 feet the road was surfaced for the full width of 22 feet with either sand-clay or adobe obtained from the right of way, and on two sections totaling 1,000 feet it was surfaced for a width of 15 feet, making a total surfaced area of 12,017 square yards.

One 6 by 2 foot reinforced-concrete slab culvert 20 feet long was built. A 3-inch plain concrete floor was laid between footings to prevent scour. The end and abutment walls were also plain concrete. The total cost of the culvert was $254.53. The principal items of cost are: Excavation and backfill, 20 cubic yards at $0.525 per cubic yard, $10.50; hauling materials an average of 3 miles, $72.60; building forms, $5; mixing and placing 16.4 cubic yards of concrete at $2.48 per cubic yard, $40.75; cutting and placing 320 feet of steel at $0.026 per linear foot, $8.30; cement, 16 barrels at $2.35 per barrel, $37.60; creek sand ready for use, not including hauling, 2 cubic yards at $1.65 per cubic yard, $3.30; gravel ready for use, 12 cubic yards at $1.85 per cubic yard, $22.20; crushed stone, 2 cubic yards at $2.75 per cubic yard, $5.50; lumber for forms, 914 feet b. m. at $0.033 per foot, $29.82; steel reinforcing rods, 523 pounds at $0.035 per pound, $18.31; nails, $0.40; wire, $0.25; making a total of $137.15 for labor and $117.38 for material.

The equipment used was 2 grading plows, 2 rooter plows, 8 No. 2 wheel scrapers, 5 slip scrapers, 1 road machine, 1 road drag, and necessary picks, shovels, etc. The total cost of the work, excluding the concrete culvert, was $1,056.70, or $0.088 per square yard. Labor was $1.50 per day and teams $4.50 per day.

Freestone County, Teague, Tex.—The work of constructing a sand-clay road east from Teague toward Dew was begun on April 2, 1914, and completed April 18, 1914. No time was lost on account of bad weather or other causes. The surrounding country is rolling. The top soil is sand. From 6 to 60 inches below the surface clay is found.

The road was graded 24 feet wide for a distance of 5,330 feet. The maximum grade of 3.3 per cent was changed to 2.9 per cent. The maximum cut was 6 inches and the maximum fill 7 inches. About 3,755 feet of the road had previously been surfaced with clay, and on this portion the work consisted in mixing sand in with the clay surface and reshaping the road. It was necessary to build a complete surface on the remaining 1,575 feet, which was through sand. After this old sand road was shaped up it was surfaced to a width of 15 feet with new clay obtained from the roadside or near-by pits, making an area of 2,625 square yards. This surfacing was broken up and mixed with the sand underneath by the use of a plow and harrow. Water was used to aid in the mixing. The surface was then shaped with a grader, rolled, and dragged. The equipment consisted of three Fresno scrapers, plow, sprinkling wagon, disk harrow, grading machine, drag, and a horse roller.

A 20-inch corrugated-iron culvert, 28 feet long, with concrete end walls, was taken up and relaid at a cost of $20.

The cost of excavation with Fresno scrapers was $89.75; trimming shoulders, ditches, and cleaning out culvert channels, $9.56; dragging, $3.40; shaping with grader, $35.50; general expenses, including foreman, $62.15. The cost of surfacing was: Placing clay on subgrade, $43.87; plowing and harrowing, $103.44; shaping, $14; sprinkling, $24.38; rolling, $23; making a total cost for the work, exclusive of drainage structures, of $415.05, which includes $6 for surveying. Teams were $2.50 per day without drivers, and laborers $1.50 per day of eight hours.

TOPSOIL ROADS.

APACHE COUNTY, ST. JOHNS, ARIZ.—Construction work was begun in Apache County, Ariz., on the Big Hollow Road, which extends west from St. Johns toward Holbrook, on August 28, 1913, and completed January 15, 1914. Two days were lost on account of bad weather. The grading work was suspended from October 8, 1913, to January 7, 1914, while the culverts and bridges were being built. The surrounding country is very hilly. From station 6+00 to 53+00 the soil is an adobe, very muddy and sticky in wet weather; from station 53+00 to 61+15 the soil is gravelly, providing a fair natural road surface.

The road was graded for a length of 5,515 feet, 20 feet wide in cuts and 16 feet wide in fills, a total of 9,210 square yards. The volume of earth moved was 6,280 cubic yards. The maximum cut was 3.2 feet and the maximum fill was 4.4 feet. The maximum grade was reduced from 10.7 per cent to 6.5 per cent. The earth was taken from borrow ditches along the side of the road with plows, Fresnos, slips, and grader.

The road was surfaced from station 7+00 to station 53+00. From stations 7 to 33 a subgrade was prepared, and the material, a natural sand-clay mixture, combined with a small amount of soft limestone, was spread to a depth of 8 inches. From stations 33 to 53 the material, which is similar to a loam, was spread to a depth of 10 inches at the center and tapered to zero at the edges. The width of surfacing material throughout was 8 feet and the crown three-fourths inch to the foot. The total area surfaced was 4,090 square yards. There were 495 cubic yards of gravel hauled an average of three-fourths mile, and the remaining 385 cubic yards were hauled an average of one-fourth mile. The gravel was loosened with a rooter plow and loaded by hand into 1-yard dump wagons. It was dumped from these wagons onto the subgrade and spread with a hoe.

Four drainage structures were built. At station 34+50 a 60-inch corrugated iron culvert was placed, 24 feet long, with concrete end walls and wings. The 60-inch corrugated pipe cost $6.15 per linear foot delivered at St. Johns, and the 48.5 cubic yards of concrete cost $14.78 per cubic yard. The total cost of the structure was $864.40.

At station 40+50 a semicircular corrugated-iron arch bridge, 14-foot span, with concrete abutments, parapets, and wings, was erected. The cost of concrete work was $15.45 per cubic yard for 132 cubic yards, and the reinforcement cost $34, making the total cost, exclusive of the 14-foot semicircular section of corrugated iron, $2,073.40.

At station 45+50 a concrete arch bridge was built of three 14-foot spans of semicircular corrugated-iron sections, with concrete abutments, piers, parapets, etc. The cost for the concrete work was $19.13 per cubic yard for the 195 cubic yards. The reinforcement cost $42.50, and the removal of an old standing wall was $50, making the total cost for the structure, excluding the cost of the three 14-foot span corrugated-iron sections, amount to $3,822.85.

At station 51+00 a 30-inch corrugated-iron culvert was built, 20 feet long, with concrete end walls. The cost of the 30-inch pipe delivered at St. Johns was $2.94 per linear foot. The cost of the concrete was $33.61 per cubic yard for the 4.5 cubic yards, making a total cost for the culvert of $210.05.

The total cost for culverts and bridges was $6,970.70. Cement was $1.54 per bag delivered at St. Johns. The contract price for excavation was $0.25 per cubic yard for 6,280 cubic yards, or $1.570, and for surfacing it was $1.10 per cubic yard for 880 cubic yards, or $968, which is $0.237 per square yard. The total cost of the road, including excavation, surfacing, and drainage structures, was $9,508.70, or $9,102.72 per mile.

Gates County, Sunbury, N. C. (Section 1).—Two sections of object-lesson road were constructed at Sunbury during the fiscal year, and will be described separately. Work was started on the first section, extending from Sunbury northward toward Suffolk, on October 29, 1913, and completed December 2, 1913, with a loss of two days on account of bad weather. The adjacent land is level and the natural soil is a sandy loam from the beginning to station 5+75; clay from 5+75 to 15+00; sandy loam from 15+00 to 20+00. A total length of 2,300 feet was graded 30 feet wide in cuts and 25 feet wide in fills. Earth was excavated to the amount of 450 cubic yards, and the average haul was 150 feet, with a maximum haul of 200 feet.

The road was surfaced for 850 feet to a width of 15 feet, making 1,416 square yards. A topsoil type of construction was used, and the surfacing material was hauled an average distance of 1,700 feet from a pit and spread in one course to a depth varying from 10 to 12 inches before compacting. Approximately 300 cubic yards of topsoil were placed, after which the entire width of the road was harrowed, dragged, and finished with a crown of three-fourths inch to the foot. The binding qualities of the material are good, but the wearing qualities are only fair.

Cross drains of wood were built at stations 5+75 and 10+00.

The equipment consisted of a disk harrow, tooth harrow, plank drag, steel drag, drag scraper, two road graders, two plows, and a few carts. The total cost of the road was $382.09, and the principal items of cost were as follows: Clearing and grubbing, $35.18; rough grading, 6,930 square yards at $0.0092 per square yard, $63.99; fine grading, 6,930 square yards at $0.00087 per square yard, $6.04; culvert excavation, 10 cubic yards at $0.495 per cubic yard, $4.95; cutting poles for culverts, 10 poles at $0.06 per pole, $0.60; building wooden culvert, $1.35; loosening and loading top soil, 300 cubic yards at $0.0491 per cubic yard, $14.75; hauling top soil, 300 cubic yards at $0.2047 per cubic yard, $61.42; spreading top soil, 300 cubic yards at $0.0172 per cubic yard, $5.16; excavating and spreading clay, 450 cubic yards at $0.2056 per cubic yard, $92.55; mixing topsoil, 2,390 square yards at $0.00202 per square yard, $4.83; compacting with tooth harrow, 4,400 square yards at $0.0006 per square yard, $2.64; trimming shoulders and ditches, $3.52; general expenses, $46.09; hauling culvert material, $2.68; topsoil purchased, $20; explosives, $5.63; other materials, $10.71. The above costs were based upon a labor cost of $1.35, and a cost for mules of $1 per day of nine hours.

GATES COUNTY, SUNBURY, N. C. (SECTION 2).—Work was begun on the second section, extending from Sunbury southward toward Milldam, on December 2, 1913, and continued to January 14, 1914, with a loss of one day on account of bad weather and a loss of 12 days due to other causes. The adjacent land is level, and the natural soil is a clay from station 0+00 to 1+70; sandy soil from 1+70 to 3; clay from 3 to 8; sandy soil from 8 to 17+50. A total length of 1,750 feet was graded 30 and 40 feet wide in cuts and 25 feet wide in fills. Earth was excavated to the amount of 550 cubic yards, 300 cubic yards of which were excavated from ditches and used on the road. Approximately 2,468 square yards of road were surfaced with 436 cubic yards of topsoil.

At station 15 a 16-inch corrugated metal culvert 38 feet long was placed and at station 15+75 a blind drain 20 feet long was constructed.

The total cost of the road was $354.19, which is at the rate of $0.144 per square yard, exclusive of drainage structures. The principal items of cost were as follows: *Grading:* Clearing and grubbing, $24.89; plowing $6.98; work done with drag scrapers, $21.16; dump carts, $23.55; handwork, $3.30; grader work, $4.28; digging ditches, $66.20; trimming shoulders, $28.77; superintendence, $32. *Surfacing:* Preparing subgrade, $13.56; stripping, $3.82; loading and hauling, $60.94; spreading, $8.45; mixing, $1.67; shaping, $3.76; compacting, $3.17; superintendence, $13.50; surfacing materials, $16.60; general expenses, $12.05. *Drainage structures:* Excavation, $1.20; hauling, $1.97; building wall, $1.20; placing pipe, $1.17. The above costs were based on labor at $1.25 and $1.50, and teams including driver at $3, per day of 10 hours.

DAVIDSON COUNTY, THOMASVILLE, N. C.—Work was begun on a topsoil road leading from Thomasville toward Randolph County on July 31, 1913, and completed on September 20, 1913, with a loss of eight days on account of bad weather. The adjacent land is rolling, and the natural soil is a yellow clay from station 0 to 20, except for rock ledges between station 4+00 and 4+50; station 10+50 and 11+25; station 14+75 and 15+25. From station 20 to 23 is gray topsoil, and from station 23 to 25 is a red clay. Scarcity of sand was the reason for using topsoil in the road surface instead of following the regular method of sand-clay construction. A total length of 3,500 feet was graded 30 feet wide in cuts and 25 feet wide in fills.

Earth was excavated to the amount of 3,359 cubic yards, and the rock excavation amounted to 311 cubic yards. The average haul for all excavation was 375 feet, and the maximum haul 725 feet. The road was surfaced with topsoil 15 feet wide for a distance of 1,200 feet, making 2,000 square yards. This required 444 cubic yards of material, which was hauled an average distance of 1,000 feet. The topsoil was spread by hand and with a grader.

Two concrete culverts were replaced and one new concrete culvert was constructed, all of which were provided with stone head walls.

The equipment consisted of 1 road grader, 4 wheeled scrapers, 8 pan scrapers, and 2 road plows. The total cost of the road was $1,199.19, including culverts, which is at the rate of $0.60 per square yard. The principal items of cost were as follows: Excavation at $0.24 per cubic yard, $882.49; shaping at $0.0444 per square yard, $185.25; culvert pipe at $0.75 per linear foot, $22.50; labor on same, $7.75; loading topsoil at $0.1568 per cubic yard, $18.50; hauling same to road at $0.1525 per cubic yard, $18; spreading topsoil at $0.0318 per cubic yard, $3.75; trimming shoulders, $8.25; shaping topsoil, $4.50; explosives, $32.20; general expenses, $16. Labor was paid $1.25 and teams $3 for 10-hour day.

APPOMATTOX COUNTY, APPOMATTOX, VA.—The construction work was begun on the Oakville road extending northwest from Appomattox toward Oakville on May 15, 1913, and supervision by the office representative ended May 14, 1914. During that period 36 days were lost on account of bad weather and 3 days from other causes. The surrounding country is hilly. The character of the soil from station 0 to 116 and from 162 to 178 was Cecil red clay, and from station 116 to 140 and from 145 to 162 was Iredell clay loam.

The road was graded to a width of 28 feet in cuts and 20 feet in fills for a distance of 18,100 feet. The volume of earth excavation was 24,000 cubic yards and of rock 290 cubic yards. The maximum cut was 7.3 feet and the maximum fill 14.7 feet. The maximum grade was reduced from 15 to 5 per cent. The surfacing was a gray topsoil, found in layers of from 4 inches to 8 inches in near-by blackjack oak woods. It was hauled in slat-bottom wagons an average distance of 4,700 feet and spread with rakes to a width of 16 feet and a compacted depth of 10 inches for a distance of 12,700 feet, or an area of 22,600 square yards.

It was found necessary to use a 4½-inch foundation of broken field stone in two level bottoms, totaling 3,900 feet in length.

Sixteen corrugated-iron culverts, totaling 574 linear feet, and three vitrified-clay pipe culverts, totaling 136 linear feet, were built. The sizes varied from 12 to 36 inches. Head walls are of field stone laid in cement mortar.

The equipment used consisted of plows, slip scrapers, wheelbarrows, picks, shovels, and rakes.

The work was done with a State convict gang averaging 32 men. They were furnished free to the county. The county provided foremen and all necessary equipment and running expenses. The convict labor was rated at $1 per day and teams $3 per day, including convict drivers. The total cost of the work was $14,736.92, of which the county paid 45 per cent and the State furnished 55 per cent in convict labor. The principal items of cost were: Clearing and grubbing 4.6 acres at $93.90 per acre; moving 1,800 feet of fence at $0.028 per foot; moving 24 telephone poles at $2.94 each; excavation of earth, 24,000 cubic yards at $0.239 per cubic yard, and of rock, 290 cubic yards at $0.629 per cubic yard; excavation and placing culverts, 710 feet at $0.18 per foot; preparing subgrade for rock, 38,700 square yards at $0.0127 per square yard; loosening and loading soil, 4,900 cubic yards at $0.256 per cubic yard; hauling 4,900 cubic yards of soil an average distance of 4,700 feet at $0.50 per cubic yard mile; spreading 4,900 cubic yards of soil at $0.061 per cubic yard; excavation and spreading soil from side of road, 500 cubic yards at $0.252 per cubic yard; loading 1,100 cubic yards of foundation stone at $0.213 per cubic yard, and hauling the same an average of 6,800 feet at $0.378 per cubic yard mile; spreading and breaking 1,100 cubic yards of foundation stone at $0.329 per cubic yard; trimming 9,800 feet of shoulders and ditches at $0.015 per foot; maintaining 2 miles of soil road for three months at $15.91 per mile; culvert pipe, $830.06; engineering and traffic census, $149.30; and superintendence, 11.1 per cent, or $1,472.24.

EARTH ROADS.

TODD COUNTY, ELKTON, KY.—Work was begun on an earth road north from Elkton toward Claymour on October 16, 1914, and completed to station 19 on December 5, 1914, with a loss of 11 days on account of rain and other causes. The adjacent land is hilly and the natural soil is clay with a large percentage of sand. The road was graded 26 feet wide in cuts and 20 feet wide in fills for 1,900 feet. The maximum cut was 2.7 feet, the maximum fill 3.5 feet, and the total amount of excavation 1,693 cubic yards. The maximum grade of 3.69 per cent was reduced to 3.52 per cent. The grubbing and clearing was so heavy the grading could not be economically done with blade graders. Earth was loosened with plow, moved by drag and wheeled scrapers, and spread by drags and by hand. No rolling was done.

Drainage structures were constructed as follows: At 4+60 a 20-inch corrugated-iron pipe, 24 feet long, costing $28.87; at 7+24 a 24-inch corrugated-iron pipe, 24 feet long, costing $35.88; at 13+21 a reinforced-concrete box culvert, 4 by 2.5 feet and 21 feet 8 inches long, containing 9.21 cubic yards, costing $107.86, or 11.71 per cubic yard. No head walls on pipe culverts.

The equipment consisted of a road plow, drag scrapers, and four-wheeled scrapers. Labor cost $1.25 per day, foreman $2 per day, and man and team $3 per day of 10 hours. The total cost of the road, exclusive of drainage structures, was $559.92, which is at the rate of $0.1225 per square yard. The principal items of cost were: Clearing and grubbing, $102.56; excavation, at $0.232 per cubic yard; shaping, $0.00072 per square yard; and superintendence, $61.30.

Chickasaw County, Woodland, Miss.—Work was begun on the Pontitock Ridge road leading from Woodland toward Pontitock Ridge on July 9, 1913, but the representative from this office remained until July 18, 1913, just long enough to get the work well under way. The road was graded 1,200 feet in length for a width of 24 feet at the time of his departure. The adjacent land is rolling and the natural soil is clay. The road was built by subscription and donated labor and teams, and the estimated cost is based on $1 per 10 hours for labor and $3 per 10 hours for teams. On the above basis the cost to the community was $72.66, or at the rate of $0.022 per square yard.

Okmulgee County, Okmulgee, Okla.—A stretch 4,820 feet long and 20 feet wide on the road leading south from Okmulgee toward Henryetta was graded in August, 1913. The area graded was 10,711 square yards. The volume of earthwork was 3,497 cubic yards and the cost $1,365, or $0.127 per square yard, or $0.390 per cubic yard.

Five culverts were built of good hard sandstone: One 2 by 2 by 20 feet, rubble masonry, with stone slab top; two 2 by 4 by 20 feet, rubble masonry, with reinforced concrete slab; one 3 by 4 by 20 feet, rubble masonry, with reinforced concrete slab; one 3 by 5 by 20 feet, rubble masonry, with reinforced concrete slab. Two existing rubble culverts were repaired, one of which was lengthened to 20 feet. The culvert work aggregated 69.36 cubic yards and was performed under a verbal contract for $350, or $5.05 per cubic yard.

See Okmulgee, Okla., under "sand-clay road," for further information of work done on an adjoining section of road at this place.

Gibson County, Cades, Tenn.—Work was begun on an earth road extending west from Cades toward Trenton on August 3, 1914, and completed August 21, 1914. The adjacent land is quite hilly and the soil is clay with considerable sand. This road was graded with plow, scrapers, and grader to a width of 26 feet in cuts and 20 feet in fills for a length of 4,200 feet. The maximum cut was 2.5 feet and the maximum fill 2 feet. The maximum grade of 4 per cent was not changed.

The total cost of the work was $664.79, or $0.0656 per square yard. The principal items of cost were: Clearing and grubbing 2,444 square yards at $0.0089 per square yard, $21.87; excavation and embankment at $0.059 per square yard, $594.80; trimming slopes and ditches, $6.87; and superintendence, $41.25.

GIBSON COUNTY, MILAN, TENN.—Work was begun on an earth road extending north from Milan toward Cades on June 15, 1914, and completed August 18, 1914, with a loss of one day on account of bad weather and one day due to a public holiday. The adjacent land is rolling and the soil consists of clay with considerable sand. The road was graded with plow, scrapers, and grader to a width of 36 feet in cuts and 32 feet in fills for a distance of 17,600 feet. The maximum cut was 3.7 feet and the maximum fill 2.5 feet. The maximum grade of 5 per cent was not changed. Considerable grubbing was necessary.

The total cost of the work was $1,570.55, or $0.024 per square yard. The principal items of cost were: Clearing and grubbing 5,555 square yards at $0.0175 per square yard, $97.19; excavation and embankment at $0.020 per square yard, $1,319.11; trimming slopes and ditches, $8.75; and superintendence, $145.50. Labor was $1.25 and teams $3 per day of 10 hours.

ERATH COUNTY, DUBLIN, TEX.—Work was begun on a gravel-macadam road extending north from Dublin toward Stephenville on October 29, 1913, and continued until December 21, 1913, with a loss of 26 days on account of bad weather. All work was stopped on December 21, 1913, on account of a continuous season of heavy rain. The nature of the soil and the excessive rains (2.61 inches in 5 days) made work impossible. The adjacent land is rolling with low hills, and the natural soil is black, sticky clay throughout. The road was graded 30 feet wide in cuts and 21 to 24 feet in fills for a total distance of 2,600 feet; of this distance only 4,000 square yards were completely graded. The maximum cut was 1.5 feet, the maximum fill 3.8 feet, and the maximum grade on the old road of 3 per cent was reduced to 1½ per cent on the new road.

At station 2+11 a culvert of two 30-inch corrugated-iron pipes 24 feet long was built with stone masonry end walls, at a total cost for labor and material of $180.40. At station 25+90 masonry abutments were built for a 16-foot span bridge at a total cost of $250.69.

In clearing, grubbing, excavation, and embankments, and fine grading, $403.67 was expended, and on various work in preparation for surfacing with gravel, $79.39. Free labor cost $1.25 per day of eight hours, hired teams, $2.50 per day, and county teams $2.40 per day.

SUPERINTENDENCE OF COUNTY ROADS.

CALCASIEU PARISH, LA.

BRICK, GRAVEL, AND EARTH ROADS.

A model highway system was reported upon in October, 1913, involving the improvement of 142 miles of road, and a bond issue amounting to $900,000 was raised to complete the work. A department was organized by a representative of the Office of Public Roads to make surveys, prepare plans, etc., and to supervise the work of construction. On January 1, 1915, about 80 miles of road had been contracted for and nearly 60 miles completed. The contracts let also include 24 reinforced concrete culverts, 41 reinforced concrete bridges, 2 steel swing-bridges, 1 combination bridge, 14 timber culverts, 17 timber bridges, 1,540 linear feet of 12-inch concrete or tile-pipe culverts, 2,603 linear feet of 18-inch concrete or tile-pipe culverts. The material for the bridges and culverts includes 2,547 cubic yards of concrete, 185,917 pounds of reinforcing steel, and 163,000 feet b. m. of timber. The work was planned in 16 divisions, which are referred to herein as highways Nos. 1, 2, 3, etc. The total aggregate of the contracts let amounts to $597,458.79. Highways Nos. 5, 6, 7, 8, 14, and 16, totaling 62 miles, still remain to be contracted for under the $900,000 bond issue. The work done has proved so successful that steps have been taken to raise $300,000 additional for the construction of a bridge over the Calcasieu River, and to extend the highway system now being constructed.

Considerable work was done by convicts in the manufacture of concrete pipe and concrete piles. The following were the unit costs for this work:

12-inch concrete pipe at 12 cents per foot;
18-inch concrete pipe at 18 cents per foot;
15-foot concrete piles at $11.60 each;
25-foot concrete piles at $14.80 each.

A list and description of the roads on which contracts have been awarded to date follows:

Highway No. 1 consists of 9 miles of 15-foot gravel road, 6 inches thick, with earth shoulders; and 5½ miles of 9-foot brick road on a 5-inch gravel base, part with earth shoulders and part with 6-inch gravel shoulders. The shoulders are 3 feet wide. All bridges and culverts are of reinforced concrete, and the pipe culverts are provided with concrete head walls. The following unit prices obtained:

Clearing and grubbing, complete	$300.00
Excavation, per cubic yard	.195
Embankment, per cubic yard	.22
Vitrified pipe, 12-inch, per foot, complete	.70
Vitrified pipe, 18-inch, per foot, complete	1.00
Concrete pipe, 12-inch, per foot, hauling and placing only	.40
Concrete pipe, 18-inch, per foot, hauling and placing only	.50
Gravel road, per square yard	.30
Vertical fiber brick on gravel base, per square yard	1.85
Concrete piles, hauling and driving, per linear foot	1.00
Concrete, 1:2:4, per cubic yard	9.00
Concrete, 1:3:6, per cubic yard	7.50
Reinforcing steel, per pound	.03

Highway No. 2 consists of 12 miles of brick road 9 feet wide, on a 5-inch gravel base; 9 miles of 15-foot gravel road, 6 inches thick; and considerable bridge work. This work was let in three contracts.

Contract No. 1, for sections 1 and 3, was let at the following unit prices:

Clearing and grubbing, complete	$225.00
Excavation, per cubic yard	.24
Embankment, per cubic yard	.24
Vitrified pipe, 12-inch, per foot, complete	.60
Vitrified pipe, 18-inch, per foot, complete	.95
Concrete pipe, 12-inch, per foot, hauling and placing only	.40
Concrete pipe, 18-inch, per foot, hauling and placing only	.50
Gravel road, per square yard	.25
Vertical fiber brick on gravel base, per square yard	1.67

Contract No. 2, for bridges and culverts on sections 1 and 3, was let at the following unit prices:

Concrete, 1:2:4, per cubic yard	$8.10
Concrete, 1:3:6, per cubic yard	7.10
Reinforcing steel, per pound	.0575

Contract No. 3, for section 2, was let at the following unit prices:

Clearing, per acre	$7.50
Grubbing, per station	6.00
Excavation, per cubic yard	.20
Embankment, per cubic yard	.22
Vitrified pipe, 12-inch, per foot, complete	.60
Vitrified pipe, 18-inch, per foot, complete	.90
Concrete, 1:2:4, per cubic yard	12.00
Reinforcing steel, per pound	.04
Gravel road, per square yard	.23

Highway No. 3 is an 18-foot earth road 13 miles long; also 1,300 feet of timber trestle. Contract was let at the following unit prices:

Clearing, per acre	$75.00
Grubbing, per station	5.00
Excavation, per cubic yard	.26
Embankment, per cubic yard	.26
Vitrified pipe, 12-inch, per foot, complete	.71
Vitrified pipe, 18-inch, per foot, complete	1.16
Concrete pipe, 12-inch, per foot, hauling and placing only	.35
Concrete pipe, 18-inch, per foot, hauling and placing only	.65
Wood pile driven below cut-off, per foot	.70
Wood pile driven above cut-off, per foot	.55
Concrete, 1:2:4, per cubic yard	13.00
Reinforcing steel, per pound	.05
Timber, per thousand feet board measure	40.00
Iron in structures, per pound	.05

Highways Nos. 4 and 10 consist of 2½ miles of 15-foot gravel road 6 inches thick; 7½ miles of 18-foot, surfaced with 9 feet of gravel 6 inches thick, with a maximum haul of 9 miles; and 6 miles of 18-foot road with 9-foot shell, 6 inches thick in the center. The bridges and culverts on this road are all concrete. The following unit prices obtained:

Clearing and grubbing, complete	$50.00
Excavation, per cubic yard	.22
Embankment, per cubic yard	.35
Vitrified pipe, 12-inch, per foot, complete	.75
Vitrified pipe, 18-inch, per foot, complete	.95
Concrete pipe, 12-inch, per foot, hauling and placing only	.40
Concrete pipe, 18-inch, per foot, hauling and placing only	.50
Concrete piles, hauling and driving, per linear foot	.85
Concrete, 1:2:4, per cubic yard	13.00
Concrete, 1:3:6, per cubic yard	12.00
Reinforcing steel, per pound	.0225
Gravel road, per square yard	.44
Shell road, per square yard	.40

Two bridges for the Intercoastal Canal, for highways Nos. 6 and 8, respectively, were contracted for at the following unit prices:

Wood pile driven below cut-off, per foot	$0.80
Wood pile driven above cut-off, per foot	.80
Concrete, 1:2:4, per cubic yard	13.85
Concrete, 1:3:6, per cubic yard	13.10
Supply and erection of steel work and turning machinery and the construction of two bridges	6,580.00

Highway No. 9 consists of 10 miles of earth road with timber bridges. Concrete pipe culverts were used. Drainage was difficult, as the road runs through low marshes and swamps. The following unit prices obtained:

Clearing, per acre	$75.00
Grubbing, per station	5.00
Excavation, per cubic yard, complete	.28
Embankment, per cubic yard, complete	.28
Vitrified pipe, 12-inch, per foot	.71
Vitrified pipe, 18-inch, per foot	1.16
Concrete pipe, 12-inch, per foot, hauling and placing only	.35
Concrete pipe, 18-inch, per foot, hauling and placing only	.65
Wood pile driven below cut-off, per foot	.70
Wood pile driven above cut-off, per foot	.55
Concrete, 1:2:4, per cubic yard	13.00
Reinforcing steel, per pound	.05
Timber, per thousand feet board measure	40.00
Iron in structures, per pound	.05

Highways Nos. 12 and 13 consist of 4 miles of earth road and 1½ miles of gravel road 15 feet wide and 6 inches thick. The following unit prices obtained:

	No. 12.	No. 13.
Clearing and grubbing, complete	$560.00	$360.00
Excavation, per cubic yard	.22	.22
Vitrified pipe, 12-inch, per foot, complete	.70	.75
Vitrified pipe, 18-inch, per foot, complete	1.00	1.00
Concrete pipe, 12-inch, per foot, hauling and placing only	.55	.55
Concrete pipe, 18-inch, per foot, hauling and placing only	.75	.75
Concrete, 1:2:4, per cubic yard	11.00	11.50
Reinforcing steel, per pound	.04	.04
Gravel road, per square yard		.25

BENNINGTON COUNTY, VT.

BITUMINOUS CONCRETE.

BENNINGTON, VT.—Work was begun on a bituminous concrete road extending east from Opera Hall toward Woodford on the main street on August 18, 1913, and completed on September 1, 1913. One day was lost on account of bad weather. The adjacent land is level.

The surfacing was placed on an old macadam road, which was torn up, reshaped, and rolled. The average haul from the siding to the road was 1 mile. The bituminous concrete was spread cold by stone hooks and rakes over an area of 4,851 square yards. This was laid in two courses, respectively 3½ inches and one-half inch in depth.

The total cost of the work was $3,786.90, which is at the rate of $0.78 per square yard.

MACADAM WITH BITUMINOUS SURFACE TREATMENT.

BENNINGTON, VT.—Work was begun on bituminous surface treatment of macadam road extending south from Bennington Center toward Pownal, on the Everett Road, on May 5, 1913, and completed on September 20, 1913, with a loss of 45 days from various causes. The adjacent land is hilly and the natural soil is clay with one section of ledge.

The road was graded 19 feet wide in both cuts and fills for a distance of 1,980 feet through the entire length for a width of 14 feet, or an area of 3,080 square yards. This was surfaced as follows: Eight inches of crusher-run field stone was laid in one course and rolled. Owing to a deficiency of binder in the crusher-run stone, sand was added; this was coated by hand sprinkler with about one-third gallon to the square yard of bituminous material and again covered with sand.

One 4 by 3 foot stone culvert 22 feet long was laid.

The funds were raised one-half by private subscription and one-half by the State. The total cost of the work was $2,551.45, or $0.829 per square yard.

MACADAM ROAD.

ARLINGTON, VT.—Work was begun on a macadam road extending west from East Arlington toward the Arlington Depot on the East Road on August 4, 1913, and completed on October 29, 1913. Fifteen days were lost from various causes. The adjacent land is swampy on the south and hilly on the north, with a natural soil of clay and loam.

The road was graded 22 feet wide in both cuts and fills for a distance of 2,004 feet. The maximum cut was 0.75 foot, the maximum fill 2 feet, and the maximum grade on the old road of 4 per cent was reduced to 3 per cent on the new road. A macadam surface 18 feet wide, making an area of 4,008 square yards, was laid with a first course of 9 inches of crushed local stone and a depth of 3 inches loose gravel surface. No roller was used.

One thousand six hundred feet of side drain, an equal amount on either side, was constructed, using screened gravel and tailings from the crusher.

The total cost of the work was $2,603.01, or $0.650 per square yard.

STAMFORD, VT.—Work was begun on a macadam section of the Village Road extending east from Stamford toward Readsboro on June 9, 1913, and completed on October 25, 1913, with 72 days' loss of time from various causes. The adjacent land is hilly and the natural soil sandy. The road was graded 21 feet wide in both cuts and fills for 1,500 feet. The maximum cut was 1 foot and the maximum fill 2 feet. The maximum grade of 3 per cent was reduced to 2 per cent.

A surface of unrolled macadam was laid for 1,500 feet, 14 feet wide, making 2,333 square yards. Crushed field stone was used as a surfacing material, and this was laid loose 6 inches thick and then covered with a coating of pit gravel. Three 12-inch and one 14-inch metal pipe culverts were placed at a cost of $113.94.

The total cost of the road, exclusive of drainage structures, was $801.98, which is at the rate of $0.344 per square yard, or $2,822.97 per mile.

GRAVEL ROADS.

ARLINGTON, VT. (No. 1).—Work was begun on a gravel road extending south from Arlington toward Shaftsbury on the south road on July 7, 1913, and completed on September 20, 1913, with 24 days lost from various causes. The adjacent land is swampy on the east, mountainous on the west, and the natural soil is sandy and saturated by underground springs feeding into the lowlands. This ground is unstable and subject to frost action.

The road was graded 21 feet wide in both cuts and fills for a distance of 4,150 feet. This was then surfaced 16 feet wide, making an area of 7,378 square yards, with 8 inches of gravel of good quality hauled 1,000 feet.

The total cost of the work was $728.71, or $0.099 per square yard. The principal items of cost were: Excavation, 1,000 cubic yards of earth and 10 yards of rock, $307.90; surfacing, $385.98; miscellaneous, $34.83.

ARLINGTON, VT. (No. 2).—Work was begun on a gravel road extending north from West Arlington toward Sandgate on September 24, 1913, and completed on November 1, 1913, with 10 days lost from various causes. The adjacent land is swampy on the east, mountainous on the west, and the natural soil is saturated clay with some disintegrated rock.

The road was graded 18 feet wide in both cuts and fills for a distance of 1,039 feet. This was surfaced 14 feet wide for a distance of 742 feet, making an area of 1,154 square yards. The gravel, which was laid 8 inches in depth, was hauled 1,000 feet.

One 18-inch concrete pipe culvert was laid and one 3 by 4 foot stone culvert extended.

The total cost of the work was $410.77.

ARLINGTON, VT. (No. 3).—Work was begun on a gravel section extending west from West Village toward New York on the west road on November 1, 1913, and completed on November 26, 1913. Nine days were lost from various causes. The adjacent land is swampy on the south, mountainous on the north, and the natural soil is clay.

The road was graded 26 feet wide in both cuts and fills for a distance of 495 feet. A width of 20 feet, or a total area of 1,100 square yards, was surfaced with 8 inches of gravel, hauled 1,000 feet.

One 1½ by 1½ foot culvert 24 feet long was rebuilt.

The total cost of the work was $289.31, or $0.263 per square yard.

ARLINGTON, VT. (No. 4).—Work was begun on a gravel road extending north from Arlington toward Sunderland on October 30, 1913, and completed on November 12, 1913, with a loss of five days for various causes. The adjacent land is low and the natural soil is loam.

The road was graded 26 feet wide in fills for a distance of 495 feet, with a maximum fill of 3 feet. This was surfaced 22 feet wide the whole length, making an area of 1,210 square yards. The gravel was hauled an average distance of 400 feet and laid to a depth of 8 inches. The bowlders and cobblestones from the pit were used for foundation.

The total cost of the work was $201.95, or $0.167 per square yard.

BENNINGTON, VT. (No. 1).—Work was begun on a gravel section extending north from Bennington Village toward North Bennington on the Robinson Road on April 28, 1913, and completed November 29, 1913, with 118 days lost from various causes. The adjacent land is low and level and the natural soil is clay and loam.

The road was graded 22 feet wide in both cuts and fills for a distance of 1,318 feet. The entire length for a width of 14 feet, or an area of 2,050 square yards, was surfaced with pit gravel 8 inches thick, hauled 1½ miles. This work was entirely in fill with a maximum of 2.5 feet, and most of the material was taken from a choked channel. Bowlders and cobbles were used for a foundation. The material was all hauled in slat-bottom wagons.

One 16-inch metal culvert was built, at a cost of $24.

The total cost of the work was $2,648.17, or $1.29 per square yard.

BENNINGTON, VT. (No. 2).—Work was begun on a gravel section extending north from Bennington toward Shaftsbury on the Harwood Hill Road on September 16, 1912, and completed on October 1, 1913, with a loss of 40 days because of bad weather. In addition work was shut down for the winter, from December 14, 1912, to April 10, 1913. The adjacent land is hilly and the natural soil is clay and rock.

The road was graded 22 feet wide in both cuts and fills for a distance of 3,680 feet. The maximum cut was 6 feet, the maximum fill 6 feet, and the maximum grade of 15 per cent was reduced to a maximum of 8 per cent. This work was done by contract under specifications prepared by the Office of Public Roads and approved by the State highway department. The road was surfaced 8 inches deep and 14 feet wide throughout its entire length, making an area of 5,724 square yards. The gravel was hauled 2 miles. A horse roller was used for the gravel surface.

Four 12-inch metal pipe culverts 30 feet long, with concrete head walls, and one 3 by 3 foot concrete culvert were built; and 566 feet of standard Massachusetts V-drain, 758 feet of 6-inch standard side drain, and one catch basin were constructed.

The total cost of the work was $8,948, or $1.561 per square yard. The main items of expense were: 2,530 cubic yards of earth excavation at $0.50 per cubic yard, $1,265; 1,783 cubic yards of rock excavation at $3 per cubic yard, $5,349; surfacing at $0.244 per square yard, $1,394.50; V-drain at $0.50 per foot, $283; side drain at $0.40 per foot, $303.20; 12-inch culvert pipe at $1.20 per foot, $144; concrete work, $145; and miscellaneous work, $64.30.

BENNINGTON CENTER, VT.—Work was begun on a gravel section extending west toward Bennington Center on the west main road September 2, 1913, and completed November 1, 1913. Twelve days were lost on account of bad weather. The adjacent land is hilly, and the natural soil is saturated clay.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,300 feet. An area of 2,600 square yards, or the entire length 18 feet wide, was surfaced with pit gravel 8 inches deep, hauled 2 miles. The maximum cut was 1 foot, the maximum fill 1.5 feet, and the maximum grade of 13 per cent was reduced to 9 per cent.

The drainage structures were: Five 6-inch cross drains and one 18-inch metal pipe culvert; seven brick catch basins; and 1,472 feet of standard Massachusetts 6-inch tile side drain covered with crushed stone 3 inches in size.

The work was done by contract. The principal items of cost were: Earth excavation, $141; shaping subgrade, $93; culvert pipe and labor, $100; side drains and labor, $883.20; surfacing, $450.75; rock excavation, $6; catch basins, $217.31; making a total cost of $1,891.26, or $0.729 per square yard.

DORSET, VT. (No. 1).—Work was begun on a gravel road extending north from Dorset toward Rupert on the west road on June 25, 1913, and completed on August 30, 1913. Twenty-eight days were lost from various causes. The adjacent land is hilly, and the natural soil gravel and sand.

The road was graded 18 feet wide in both cuts and fills for 1,452 feet. The surface, 16 feet wide, making an area of 2,581 square yards, was laid 8 inches thick with gravel from alongside the road. The maximum cut was 4 feet, the maximum fill 4 feet, and the maximum grade of 12 per cent was reduced to a maximum of 6 per cent.

The total cost of the work was $286.79, or $0.111 per square yard.

DORSET, VT. (No. 2).—Work was begun on a gravel road extending north from North Dorset toward Mount Tabor on September 15, 1913, and completed on November 1, 1913. Ten days were lost on account of bad weather. The adjacent land is hilly, and the natural soil is sandy.

The road was graded 21 feet wide in both cuts and fills for a distance of 1,200 feet. The gravel was hauled from a point a half mile distant and placed to a depth of 8 inches and a width of 14 feet, making a surfaced area of 1,867 square yards. The maximum cut was 8 feet, the maximum fill 3 feet, and the maximum grade of 7 per cent on the old road was reduced to 4 per cent on the new road.

Three 12-inch metal culverts were built with concrete head walls.

The total cost of the work, including culverts, was $754.41, or $0.404 per square yard.

DORSET, VT. (No. 3).—Work was begun on a gravel section extending north from East Dorset toward North Dorset, on Hairpin Curve Road, on July 28, 1913, and completed on September 13, 1913, with four days lost on account of bad weather. The road, as relocated, eliminates the Hairpin Curve. The adjacent land is hilly and the natural soil is gravel and bowlders.

The road was graded 21 feet wide in both cuts and fills for a distance of 1,033 feet. This was surfaced the whole length and width, or 2,410 square yards, with gravel obtained from alongside the road and placed to a depth of 8 inches. The maximum cut was 17 feet, the maximum fill 22 feet, and the maximum grade of 10 per cent was reduced to 5 per cent. Work was done with road graders, harrow, New York hone, and split-log drag. A crib of large trees and stumps was built at one point to prevent sliding of the embankment, and a guard rail was also built.

The total cost of the work was $713.70, or $0.296 per square yard.

DORSET, VT. (No. 4).—Work was begun on a gravel road extending south from East Dorset toward Manchester on the Cemetery Road June 17, 1913, and completed July 12, 1913, with a loss of two days because of bad weather. The adjacent land is rolling and the natural soil is gravel and loam.

The road was graded 21 feet wide in both cuts and fills for a distance of 630 feet. The full length and width, or 1,470 square yards, was surfaced 8 inches thick with gravel, hauled one-half mile. The maximum cut was 2 feet, the maximum fill 4 feet, and the maximum grade of 8 per cent on the old road was reduced to 6 per cent on the new road.

The total cost of the work was $346.19, or $0.235 per square yard.

DORSET, VT. (No. 5).—Work was begun on a gravel section extending north from the cemetery toward the hotel on the village road June 16, 1913, and completed on October 11, 1913, with a loss of 81 days for various causes. The adjacent land is rolling and the natural soil is clay.

The road was graded 27 feet wide in both cuts and fills for a distance of 627 feet. The maximum fill was 1 foot and the maximum grade on the old road of 2 per cent was reduced to 0.3 per cent on the new road. The gravel, which was hauled 1 mile, was laid 8 inches thick and 23 feet wide, making an area of 1,603 square yards. Transverse leeches of screened gravel were placed frequently.

One 3 by 3 foot dry masonry culvert was built.

The total cost of the work was $392.39, or $0.244 per square yard.

GLASTONBURY, VT.—Work was begun on a gravel road extending south from Glastonbury toward South Shaftsbury June 2, 1913, and completed August 30,

1913. Fifty-eight days were lost from various causes. The adjacent land is mountainous and the natural soil is gravel.

The road was graded 18 feet wide in both cuts and fills for a distance of 600 feet. An area of 1,066 square yards was surfaced 16 feet in width and 6 inches thick with gravel, hauled one-half mile in stone boats. The maximum cut was 4 feet, the maximum fill 2 feet, and the maximum grade of 8 per cent was reduced to 5 per cent.

Three 20-foot stone culverts were built, 10, 12, and 24 inches, respectively, in diameter.

The total cost of the work was $289, or $0.271 per square yard.

Landgrove, Vt.—Work was begun on a gravel section on the Ideal Tour Road east from Landgrove Hollow toward Londonderry June 10, 1913, and completed August 30, 1913, with 39 days lost from various causes. The adjacent land is mountainous and the soil rocky throughout.

The road was graded to a width of 21 feet in both cuts and fills for a distance of 650 feet. The maximum cut was 2 feet and the maximum fill 5 feet. The maximum grade on the old road was 14 per cent, which was reduced to 8 per cent on the new road. A surface of pit gravel was laid to a width of 14 feet, 8 inches thick, making a surfaced area of 1,011 square yards.

Two metal culverts, 24 feet long and 16 and 24 inches in diameter, were placed at a cost of $48. The total cost of the road, exclusive of culverts, was $472.48, which is at the rate of $0.4673 per square yard.

The equipment consisted of plows, shovels, slat-bottom wagons, rákes, harrows, and a split-log drag. Labor cost $1.75 per day, foreman $2.25 per day, and teams $4 per day of 9 hours.

Manchester, Vt.—Work was begun on a hardpan gravel road extending north from Manchester toward Peru August 18, 1913, and completed October 18, 1913. Seven days were lost on account of bad weather. The adjacent land is rolling and the natural soil sand and stone.

The road was graded 26 feet wide in both cuts and fills for a distance of 2,310 feet. The maximum cut was 3 feet, the maximum fill 2 feet, and the maximum grade of 7 per cent was reduced to 4 per cent. A natural surfacing of hardpan 22 feet wide, making an area of 5,646 square yards, was laid after being hauled 1 mile.

Two 2 by 2 foot concrete culverts were built and two 12-inch metal-pipe culverts were laid.

The total cost of the work was $1,427.58, or $0.253 per square yard.

Peru, Vt. (No. 1).—Work was begun on a hardpan gravel section extending east from Peru toward Landgrove on the Ideal Tour Road June 1, 1913, and completed October 25, 1913, with a loss of 98 days for various causes. The adjacent land is hilly and the natural soil is clay gravel.

The road was graded 26 feet wide in both cuts and fills for a distance of 644 feet. The maximum cut was 1 foot, the maximum fill 4 feet, and the maximum grade of 6 per cent was not changed. The road was surfaced 22 feet wide, making an area of 1,574 square yards, with a natural clay-gravel "hardpan."

One 3½ by 4 foot dry-stone culvert was built.

The total cost of the work was $237.48, or $0.150 per square yard, of which $39.25 was expended for the culvert.

Peru, Vt. (No. 2).—Work was begun on a gravel road extending east from Peru toward Landgrove on the Ideal Tour Road May 19, 1913, and completed November 22, 1913. The time lost from various causes was 73 days. The adjacent land is hilly and the natural soil is loam and gravel.

The road was graded 21 feet wide in both cuts and fills for a distance of 5,313 feet. The maximum cut was 6 feet, the maximum fill 4 feet, and the maximum grade of 11 per cent on the old road was reduced to 8 per cent.

The road was surfaced full width, or an area of 12,397 square yards, with gravel from within the road limits and from pits alongside the road.

Three 24-foot stone culverts were built of the following dimensions: 4 by 2.5 feet, 2 by 2.5 feet, and 2 by 2 feet.

The total cost of the work was $2,001.89, or $0.161 per square yard.

Pownal, Vt.—Work was begun on a road extending north from Pownal toward North Pownal on September 8, 1913, and completed on October 18, 1913, with five days lost from various causes. The adjacent land is hilly and the natural soil is gravel and clay.

The road was graded 24 feet wide in both cuts and fills for a distance of 1.500 feet. The maximum cut was 2 feet, the maximum fill 2 feet, and the maximum grade of 6 per cent on the old road was reduced to 4 per cent on the new road. A natural gravel was obtained from a near-by source and the road surfaced 22 feet wide, or an area of 3,666 square yards. Telford foundation 12 feet wide and 2 feet thick was placed on 800 feet of this road.

The total cost of the work was $839.56, or $0.228 per square yard.

Readsboro, Vt.—Work was begun on a "hardpan" gravel road extending east from Heartwellville toward Readsboro on August 25, 1913, and completed on September 13, 1913. The time lost on account of bad weather was two days. The adjacent land is hilly and the natural soil is "hardpan."

The road was graded 19 feet wide in both cuts and fills for a distance of 1,000 feet. The maximum fill was 3 feet and the maximum grade of 3 per cent on the old road was reduced to 1 per cent. The road was surfaced by hauling in hardpan and leveling it with a split-log drag.

The total cost of the work was $400, or $0.190 per square yard.

Rupert, Vt. (No. 1).—Work was begun on a gravel road extending east from Rupert toward Dorset on May 19, 1913, and completed on August 22, 1913, with 10 days lost on account of bad weather. The adjacent land is hilly and the natural soil is a slate gravel.

The road was graded 24 feet wide in both cuts and fills for a distance of 4,050 feet. The maximum cut was 2 feet, the maximum fill 6 feet, and the maximum grade of 6 per cent on the old road was reduced to 4 per cent on the new road. Gravel from a near-by pit was laid for a width of 18 feet, or an area of 8,100 square yards.

One 12-inch and one 24-inch corrugated-iron pipe culverts were laid; also one 3 by 2 foot concrete box culvert.

The total cost of the work, including culverts, was $2,099.78, or $0.259 per square yard.

Rupert, Vt. (No. 2).—Work was begun on a gravel road extending north from Rupert toward Pawlet on September 1, 1913, and completed on September 16, 1913, with one day lost on account of bad weather. The adjacent land is level and swampy and the natural soil is gravel and loam.

The road was graded 18 feet wide in both cuts and fills for a distance of 495 feet. The maximum fill was 5 feet and the maximum grade of 2 per cent on the old road was reduced to 1 per cent on the new road. A gravel surface obtained from the river bed was laid the full width, a total area of 990 square yards.

The total cost of the work was $704.28, or $0.71 per square yard.

SANDGATE, VT.—Work was begun on a gravel section on the Bear Mountain Road north from Sandgate toward Bear Mountain on August 18, 1913, and was entirely completed October 15, 1913, with seven days' loss of time on account of bad weather. The adjacent land is mountainous and the soil is a clay.

The road was graded 18 feet wide in cuts and fills for a distance of 1,171 feet. The maximum cut was 4 feet, the maximum fill 2 feet, and the original maximum grade, which was 9 per cent, was reduced to 6 per cent. A surface of unrolled gravel was laid for 1,171 feet, 14 feet wide, making 1,821 square yards. The gravel used was obtained from the side of the road.

Two stone culverts 2 by 2 by 20 feet were placed.

The total cost of the completed road was $514.51, which is at the rate of $0.2825 per square yard, including drainage structures. Labor cost $1.75 per day, foreman $2 per day, and teams $4 per day of 9 hours.

SEARSBURG, VT.—Work was begun on June 2, 1913, surfacing with hardpan the road extending east from Searsburg toward Wilmington, and was entirely completed on October 25, 1913, with a loss of 31 days from various causes. The adjacent land is mountainous and the soil is clay. The road was graded 20 feet wide in both cuts and fills for a distance of 1,006 feet. The maximum cut was 2 feet and the maximum fill 4 feet. The maximum grade of 10 per cent was reduced to 8 per cent. A surface of hardpan was laid 12 feet wide for 1,006 feet, making 1,341 square yards. This hardpan was obtained from a pit at the roadside.

Six 20-foot metal culvert pipes 20 inches in diameter were placed at a cost of $141.

The principal items of cost were as follows: Labor, $1,213.58; dynamite, $41; and road drag, $2.50; making a total of $1,257.08, which is at the rate of $0.9374 per square yard, or $6,594.72 per mile, exclusive of drainage structures.

Labor was paid $1.75 per day, foreman $2.25 per day, teams $4 per day of 9 hours.

SHAFTSBURY, VT. (No. 1).—Work was begun on a gravel road extending west from Sodom toward New York on May 26, 1913, and completed September 20, 1913. Sixty-one days were lost for various causes. The adjacent land is hilly and the natural soil is clay.

The road was graded 22 feet wide in both cuts and fills for a distance of 1,000 feet. The maximum cut was 4 feet, the maximum fill 2 feet, and the maximum grade of 9 per cent was reduced to 4 per cent. A surface of gravel from near-by pits was laid 14 feet wide, making an area of 1,555 square yards.

Two 24-inch metal culverts were laid and 750 feet of underdrain was constructed.

The total cost of the work, including culverts, was $872.35, or $0.560 per square yard.

SHAFTSBURY, VT. (No. 2).—Work was begun on a gravel road running south from West Shaftsbury toward New York on August 18, 1913, and finished on September 19, 1913. Three days were lost on account of bad weather. The adjacent land is hilly and wet and the natural soil is clay.

The road was graded 22 feet wide for a distance of 1,060 feet. The maximum cut was 2 feet, the maximum fill 5 feet, and the maximum grade of 9 per cent on the old road was reduced to 4 per cent on the new road. A surface of river gravel from New York was laid 12 feet wide, making an area of 1,413 square yards.

One 24-inch and two 12-inch metal culverts with concrete head walls were built, and a berm ditch of the flare type was used.

The total cost of the work, including culverts, was $936.40, or $0.661 per square yard.

STAMFORD, VT.—Work was begun on a "hardpan" gravel road extending northeast from Stamford toward Heartwellville on August 4, 1913, and completed on August 30, 1913, with two days lost on account of rain. The adjacent land is hilly and the natural soil is loam.

The road was graded 21 feet wide in both cuts and fills for a distance of 1,419 feet. The maximum cut was 3 feet, the maximum fill 1 foot. A surface of hardpan from a near-by pit was laid 14 feet wide, making a surfaced area of 2,207 square yards.

Four hundred feet of blind drain was built.

The total cost of the work was $409.50, or $0.186 per square yard.

WINHALL, VT.—Work was begun on a "hardpan" gravel road extending east from Bondville toward Manchester on August 4, 1913, and completed on September 27, 1913. Six days were lost on account of bad weather. The adjacent land was hilly and the natural soil is hardpan and bowlder ledges.

The road was graded 21 feet wide in both cuts and fills for a distance of 2,450 feet. The maximum cut was 20 feet, the maximum fill 6 feet, and the maximum grade of 14 per cent on the old road was reduced to 8 per cent. The road was surfaced with hardpan and gravel, obtained along the roadside.

Two 12-inch and two 18-inch metal culverts, 22 feet long, were laid.

The total cost of the work, including culverts, was $1,075.53.

EARTH ROAD.

POWNAL, VT. (No. 1).—Work was begun October 20, 1913, on an earth road extending south from Bennington to Pownal and was completed November 29, 1913, with a loss of nine days on account of rain. The adjacent land is hilly and swampy and the soil a loam.

The road was graded 20 feet wide in cuts and fills for a distance of 1,450 feet. The maximum cut was 2 feet, the maximum fill 3 feet, and the grade was not changed. Material for a telford foundation was obtained from old stone walls along the roadside and laid 12 feet wide for 1,200 feet. After grading, the earth was then leveled over the rock. It was intended to surface this road with gravel later.

The total cost of the work was $816.21, which is at the rate of $0.253 per square yard, or $2,942.50 per mile. Labor cost $1.75 per day; foreman, $2.50 per day; and teams, $4.50 per day of nine hours.

POWNAL, VT. (No. 2).—Work was begun on an earth road extending north from Pownal Center toward Bennington on May 5, 1913, and completed on September 6, 1913, with 15 days lost on account of rain and bad weather. The adjacent land is hilly and the natural soil is loam, bowlders, and gravel.

The road was graded 22 feet wide in both cuts and fills for a distance of 3,600 feet. The maximum cut was 24 feet, the maximum fill 3 feet, and the maximum grade of 8 per cent on the old road was reduced to 6 per cent.

One 2 by 1½ foot stone culvert was built at a cost of $14.

The total cost of the work was $1,815.77, or $0.206 per square yard.

READSBORO, VT. (No. 1).—Work was begun on an earth road extending east from Falls toward Readsboro on May 21, 1913, and completed on October 11,

1913. Thirty days were lost from various causes. The adjacent land is mountainous and the natural soil is hardpan.

The road was graded 18 feet wide in both cuts and fills for a distance of 4,046 feet. The maximum cut was 30 feet, the maximum fill 9 feet, and the maximum grade of 11 per cent on the old road was reduced to 7 per cent.

Seven stone culverts 2 by 2 by 20 feet were built; also two 18-inch metal culverts. Leeches were placed every 200 feet. Much heavy stumping was done and a bowlder ledge was removed.

The total cost of the work, including culverts, was $2,526.58, or $0.312 per square yard.

READSBORO, VT. (No. 2).—Work was begun on an earth road extending east from Readsboro toward Whitingham on July 28, 1913, and completed on October 11, 1913. Forty-five days were lost on account of various causes. The adjacent land is mountainous and the natural soil is hardpan, which was used for surfacing the road.

The road was graded 18 feet wide in both cuts and fills for a distance of 850 feet. The maximum cut was 10 feet, the maximum fill 1 foot. A guard rail was built the full length of the road on one side.

The total cost of the work was $390.78, or $0.230 per square yard.

SHAFTSBURY, VT. (No. 1).—Work was begun on an earth road extending north from Shaftsbury Depot toward Arlington on October 13, 1913, and completed on November 19, 1913. Bad weather caused a delay of 10 days. The adjacent land is hilly and the natural soil is hardpan, which was used in the surfacing.

The road was graded 22 feet wide in both cuts and fills for a distance of 1,056 feet. The maximum cut was 19 feet, the maximum fill 2 feet, and the maximum grade was reduced from 8 per cent to 6 per cent.

One double 24-inch metal culvert was laid.

The total cost of the work, including culverts, was $778.02, or $0.301 per square yard.

SHAFTSBURY, VT. (No. 2).—Work was begun on a section of the Coal Hill Road south from South Shaftsbury toward Bennington November 20 and was completed on November 27, 1913. The adjacent land is hilly, and the natural soil is clay.

The road was graded 22 feet wide in cuts and fills for a distance of 528 feet. The maximum cut was 9 feet and the maximum fill 2 feet.

One 24-inch metal culvert 26 feet long was placed at a cost of $46.86.

The total cost of the completed road, exclusive of drainage structures, was $89.74, which is at the rate of $0.070 per square yard, or $897.40 per mile.

SUNDERLAND, VT.—Work was begun on an earth road east from Sunderland toward Arlington June 23, 1913, and the road was completed on September 27, 1913, with a loss of nine days on account of bad weather. The adjacent land is hilly and the natural soil loam and sand.

The road was graded 21 feet wide in cuts and fills for a distance of 4,356 feet. The maximum cut was 10 feet and the maximum fill 3 feet. The maximum grade of 10 per cent on the old road was reduced to a maximum of 7 per cent on the new road. The improvement consisted essentially in widening a 6-foot road to 21 feet and in placing gravel, obtained from the roadside, over the sandy portions.

One 12-inch metal-pipe culvert 24 feet long was placed at a cost of $22.70.

The total cost of the road, exclusive of drainage structures, was $713.46, which is at the rate of $0.070 per square yard, or $864.82 per mile. Labor costs $1.75 per day, foreman $2.50 per day, and teams $4 per day of nine hours.

Woodford, Vt.—Work was begun on an earth road running east from the city of Woodford toward Bennington on August 30, 1913, and completed on October 25, 1913. The time lost from various causes was 20 days. The adjacent land is mountainous, and the natural soil is clay, which was used for surfacing.

The road was graded 22 feet wide in both cuts and fills for a distance of 1,396 feet. The maximum cut was 6 feet, the maximum fill 5 feet, and the maximum grade was reduced from 17 per cent to 8 per cent.

Nine 12-inch and one 24-inch metal culverts and 396 feet of side drain were constructed.

The total cost of the work, including culverts, was $686.24, or $0.201 per square yard.

Rutland County, Vt.

BITUMINOUS MACADAM.

Pittsford, Vt.—Work was begun on a bituminous macadam road on the main line from Pittsford to Rutland July 14, 1913, and completed November 1, 1913, with a delay of 14 days for various causes. The adjacent land is hilly on the east and rolling on the west. The natural soil is sandy loam.

The road was graded 30 feet wide in both cuts and fills for a distance of 1,544 feet. The maximum cut was 1.2 feet, the maximum fill 3 feet, and the maximum grade of 1.3 per cent on the old road was reduced to 0.8 per cent. A surface of bituminous macadam was laid 16 feet wide, or for 2,745 square yards, in the following manner: Local crushed stone was placed in two 3-inch compacted courses. A bituminous material was then applied as a binder by the penetration method, using 1½ gallons per square yard. A one-half gallon flush coat was finally applied.

Three 18-inch corrugated-iron pipe culverts were laid. Two masonry culverts were repaired and lengthened, and a telford base was laid from station 4 to station 8+25.

The total cost of the work, including culverts, was $3,420.99, which is at the rate of $11,698.37 per mile, or $1.246 per square yard.

GRAVEL ROADS.

Benson, Vt. (No. 1).—Work was begun on a gravel road extending east from Benson, toward Hortonville, on September 2, 1913, and completed on September 20, 1913. Two days were lost on account of bad weather. The adjacent land is hilly and the natural soil is clay.

The road was graded 26 feet wide in both cuts and fills for a distance of 462 feet. The maximum cut was 1 foot; the maximum fill, 1.5 feet; the old maximum grade, 3 per cent; and the new maximum grade, 1.3 per cent. A surface of gravel 21 feet in width, making 1,078 square yards, was placed. The gravel was obtained from pits alongside the road.

One corrugated-iron pipe culvert 18 inches in diameter was placed.

The total cost for the work was $184.83, or at the rate of $0.171 per square yard.

BENSON, VT. (No. 2).—Work was begun on a gravel section, starting at a point 3 miles east of Benson on the main road toward Hortonville, on August 1, 1913. It was completed on August 30, 1913, with a loss of five days from various causes. The adjacent land is hilly and the natural soil brown, stiff clay.

The road was graded 26 feet wide in both cuts and fills for a distance of 2,657 feet. The maximum cut was 3 feet; the maximum fill, 3.5 feet. The maximum grade on the old road was 10 per cent and on the new road 7 per cent. Bank gravel for surfacing was obtained from pits along the roadside and placed 21 feet wide for the entire graded length, or a total area of 6,200 square yards.

Three corrugated-iron pipe culverts were placed.

The total cost of the work was $339.55, or $0.055 per square yard.

BENSON, VT. (No. 3).—Work was begun graveling a section of the turnpike extending from the north town line toward Fairhaven on May 15, 1913, and completed on June 1, 1913. The adjacent land is hilly and the natural soil seems to be about half sandy loam and half brown stiff clay.

The road was graded 26 feet wide in both cuts and fills for a distance of 891 feet. The maximum fill was 2.5 feet and the maximum grade was reduced from 1 per cent to 0.7 per cent. The graded earth was covered with waste from a slate quarry for its entire length. Gravel was then placed 21 feet wide, making an area of 2,079 square yards.

One 4 by 8 foot culvert was repaired by placing a new floor.

The total cost of the work was $432.83, or $0.208 per square yard.

BENSON, VT. (No. 4).—Work was begun on a gravel section extending north from the south town line on the stage road toward Benson April 30, 1913, and completed May 12, 1913, with a loss of two days, due to bad weather. The adjacent land is hilly and the natural soil is a brown clay.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,584 feet. The maximum cut was 1 foot and the maximum fill 1.2 feet. The maximum grade of 2.5 per cent on the old road was reduced to 1.5 per cent on the new road. Gravel was obtained from banks near by and laid 21 feet in width, making an area of 3,696 square yards.

One 15-inch corrugated-iron pipe culvert was replaced and one 2 by 2 foot masonry culvert was lengthened.

The total cost of the work was $198.45, or $0.054 per square yard.

BRANDON, VT.—Work was begun on a gravel road extending north from Brandon toward Salisbury on August 2, 1913, and completed on August 30, 1913. The adjacent land is rolling, and the natural oil is sand and a sandy loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,188 feet. The old road was very sandy, and after it had been widened and straightened a 3-inch layer of clay was applied on the subgrade before putting on the gravel. A surface of gravel was then placed 21 feet in width, making 2,772 square yards. This was compacted with a 3-ton horse roller.

Two small concrete culverts and one 18-inch corrugated-iron pipe culvert were placed.

The total cost was $635.40, or $0.229 per square yard.

CASTLETON, VT.—Work was begun on a gravel road extending south from Castleton toward Poultney on September 20, 1913, and completed October 20, 1913. Three days were lost on account of rain. The adjacent land is rolling, and the natural soil is sand.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,287 feet. The new road was widened and, where necessary, raised, making the fill of rocks and old brick. The voids were well filled with chips before surfacing. The maximum fill was 2.5 feet. A surface of gravel was laid 21 feet wide, making an area of 3,003 square yards.

Two small corrugated-iron pipe culverts were laid.

The total cost of the work was $430.88, or $0.143 per square yard.

Castleton Four Corners, Vt.—Work was begun October 23, 1913, and completed November 7, 1913, resurfacing the old State road, extending west from Castleton Four Corners toward Hydeville, with gravel.

No grading was done, simply a surface of bank gravel was placed 21 feet wide for a total distance of 2,558 feet, or a total surface area of 5,969 feet.

The total cost was $322.80, or $0.054 per square yard.

Center Rutland, Vt.—Work was begun September 1, 1913, on a gravel road starting at a point 1½ miles north of Center Rutland and extending toward Proctor. It was completed on October 1, 1913, and only two days were lost on account of bad weather. The adjacent land is rolling and the natural soil is clay.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,188 feet. The maximum cut was 2.5 feet, the maximum fill 1.9 feet, and the maximum grade was reduced from 3.9 per cent to 2.5 per cent. The road was surfaced with bank gravel for a width of 21 feet, or a total area of 2,772 square yards.

One 5 by 3 foot and one 2 by 3 foot masonry culvert and one 18-inch corrugated-iron pipe culvert were placed.

The total cost of the work, including culverts, was $596.75, or $0.215 per square yard.

Chittenden, Vt. (No. 1).—Work was begun on a gravel road extending east from Chittenden toward North Sherburne on August 15, 1913, and completed on August 30, 1913. The adjacent land is hilly and the natural soil is loam.

This strip of road is paralleled by a mountain stream, and it was necessary to build a retaining wall to protect the road. A 2-foot fill was made with borrowed material. The road was graded 26 feet wide in both cuts and fills for a distance of 350 feet. The maximum cut was 1 foot; the maximum fill, 2 feet. The maximum grade of 4 per cent was reduced to 2.8 per cent. A surface of bank gravel was laid, 21 feet in width, making an area of 817 square yards.

One 15-inch corrugated-iron culvert was placed.

The total cost of the work was $344.66, or $0.422 per square yard.

Chittenden, Vt. (No. 2).—Work was begun September 10, 1913, on a gravel road extending from 3 miles east of Chittenden toward North Sherburne. It was completed on September 30, 1913, with two days lost on account of rain. The adjacent land is hilly, and the natural soil is clay loam. The old road was very swampy, poorly drained, and low.

The maximum cut was 0.8 foot and the maximum fill was 1 foot. The road was graded 26 feet wide in cuts and fills for a distance of 500 feet. A surface of bank gravel was laid 21 feet wide, making an area of 1,166 square yards.

One 2 by 2 foot masonry culvert was lengthened and one 18-inch corrugated-iron pipe culvert placed.

The total cost of the work was $336.69, or $0.288 per square yard.

CLARENDON, VT.—Work was begun September 1, 1913, on a gravel section extending south on the Creek Road from Rutland to Wallingford. It was completed on December 14, 1913, with five days lost on account of bad weather. The adjacent land is level on the east end of the road and hilly on the west. The natural soil is clay and sandy loam, equally divided, with rock outcrops in places.

The road was graded to a width of 26 feet in both cuts and fills for a distance of 7,499 feet. More than $1,500 of the amount expended was used in rock-work to widen the road for a distance of 550 feet. In some places the ledge was 18 feet high. Before this was removed the road was only 12 feet wide. At station 40 a bad curve was eliminated by cutting through a hill and constructing a retaining wall 12 feet high. Smaller retaining walls were built at various other places and guard rails placed where necessary. The maximum cut was 4 feet and the maximum fill 3.5 feet. The maximum grade on the old road was 6 per cent, which was reduced to a maximum of 3 per cent on the new road. The surfacing material used was an excellent quality of bank gravel. It was laid 21 feet wide, a total area of 17,497 square yards.

Ten small culverts were built.

Labor cost $1.75 and $2 per day, foreman $4 per day, and teams $4.50 per 9-hour day. The total cost of the work was $6,387.90, or $0.365 per square yard.

CUTTINGSVILLE, VT.—Work was begun on a gravel loam road beginning 2 miles north of Cuttingsville and extending northwest toward East Clarendon on August 2, 1913, and completed on September 3, 1913. Three days were lost on account of rain. The adjacent land is hilly and the natural soil is loam.

The road was graded 26 feet in width in both cuts and fills for a distance of 1,023 feet. Considerable clearing and grubbing was necessary, and a section of retaining wall was built. The maximum cut was 0.5 foot, the maximum fill 3 feet, and the maximum grade was reduced from 4 per cent to 2.5 per cent. A surface of gravel loam from the excavated material was laid 20 feet wide, making an area of 2,387 square yards.

One 12-inch and one 18-inch corrugated-iron pipe culvert were laid.

The total cost of the work, including culverts, was $480.77, or $0.201 per square yard.

DANBY FOUR CORNERS, VT.—Work was begun on a gravel road extending west from Danby Four Corners toward Pawlet on August 1, 1913, and completed on August 10, 1913. The adjacent land is hilly and the natural soil is a sandy loam.

The road was graded 26 feet wide in cuts and fills for 350 feet. A surface of bank gravel was laid 21 feet wide, making an area of 817 square yards.

One 18-inch corrugated-iron pipe culvert was placed.

The total cost of the work was $161, or $0.197 per square yard.

DANBY, VT. (No. 1).—Work was begun August 10, 1913, on a gravel road beginning at a point 3 miles south of Danby and extending south toward the Bennington County line. It was completed November 15, 1913, with a loss of 12 days on account of various causes. The adjacent land is hilly on the west and level on the east side. The natural soil is sand and sandy loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 2,360 feet. Considerable rock excavation was done and 900 linear feet of retaining wall was built from 2 to 8 feet high. The maximum cut was 2 feet, the maximum fill 2 feet, and the maximum grade was reduced from 3 to 1.5 per cent. A surface of gravel was laid 21 feet wide, making an area of 5,507 square yards. The average haul of surfacing was 1 mile.

Six corrugated-iron pipe culverts were laid.

The total cost of the work was $1,832.28, or $0.333 per square yard.

Danby, Vt. (No. 2.)—Work was begun on a gravel road extending from a point 1½ miles east of Danby toward Danby Four Corners on August 15, 1913, and completed September 1, 1913. The adjacent land is hilly and the natural soil is clay.

The maximum cut was 3 feet, the maximum fill 2½ feet, and the maximum grade of 11 per cent was reduced to 9 per cent on the new road. The road was graded 26 feet wide in cuts and fills for a distance of 545 feet. A retaining wall averaging 7 feet in height for 100 feet in length was built and considerable rock was removed during the grading. A bank gravel surface was laid for a width of 21 feet, making an area of 1,272 square yards.

One 18-inch corrugated-iron pipe culvert was placed and one 3 by 3 foot masonry culvert lengthened.

The total cost of the work was $412.03, or $0.324 per square yard.

Danby, Vt. (No. 3).—Work was begun September 15, 1913, on a gravel road extending from a point 2 miles north of Danby Post Office on the Creek Road toward Wallingford and completed on October 30, 1913. Five days were lost from various causes. The adjacent land is hilly and the natural soil is clay and sand rock.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,452 feet. The maximum cut was 3 feet; the maximum fill, 4.2 feet. The maximum grade of the old road was 10.5 per cent, which was reduced to 7 per cent on the new road. A surface of bank gravel 21 feet wide was laid, making an area of 3,388 square yards.

Two masonry culverts were repaired and two 18-inch corrugated-iron pipe culverts placed.

The total cost of the work was $1,528.69, or $0.451 per square yard.

East Wallingford, Vt. (No. 1).—Work was begun on a gravel road starting 2½ miles east of East Wallingford and extending toward Mount Holly on August 12, 1913, and completed September 30, 1913, with three days lost on account of rain. The adjacent land is hilly and the natural soil clay loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,700 feet. The maximum cut was 3.5 feet, the maximum fill 3 feet, and the maximum grade of 8 per cent was reduced to 5 per cent on the new road.

Three hundred feet of telford foundation was placed, and the whole road was surfaced for a width of 21 feet with bank gravel. The surfaced area was 3,967 square yards.

Four corrugated-iron pipe culverts and one 2 by 2 foot concrete box culvert were laid.

The total cost of the work was $861.70, or $0.217 per square yard.

East Wallingford, Vt. (No. 2).—Work was begun October 2, 1913, on a gravel section 4 miles southeast from East Wallingford and extending toward Weston, on the road locally known as the "Clay Hole." It was completed November 1, 1913, and two days were lost on account of rain. The adjacent land is hilly and the natural soil clay.

The road was graded 26 feet in width in both cuts and fills for a distance of 578 feet. The maximum fill was 2 feet and the maximum grade was reduced from 3 to 1.5 per cent. The V foundation was covered with bank gravel to a width of 21 feet, giving a surfaced area of 1,349 square yards.

One stone masonry culvert was lengthened, and regulation stone and tile cross drains were put in every 20 feet to drain the V foundation, which was laid of fence stone.

The total cost of the work was $303.26, or $0.225 per square yard.

Fair Haven, Vt. (No. 1).—Work was begun August 1, 1913, on a gravel road beginning at the line between the townships of Fair Haven and Castleton and extending west toward the village of Fair Haven, and completed on August 10, 1913. The adjacent land is rolling and the soil is sandy loam.

The road was shaped 26 feet wide in both cuts and fills for a distance of 743 feet. A surface of bank gravel was placed 21 feet wide, making an area of 1,734 square yards.

One 18-inch corrugated-iron pipe culvert was placed.

The total cost of the work was $165.20, or $0.095 per square yard.

Fair Haven, Vt. (No. 2).—Work was begun on a gravel road extending west from Fair Haven toward Whitehall, N. Y., on August 12, 1913, and completed on September 3, 1913, with one day lost on account of rain. The adjacent land is rolling and the natural soil very sandy.

The old road was lightly shaped and a 3-inch layer of clay applied on the sand subgrade before putting on the gravel surface. The road was graded 26 feet wide in both cuts and fills for a total length of 2,970 feet. A gravel surface 21 feet wide, making an area of 6,930 square yards, was placed.

One 15-inch and one 18-inch corrugated-iron pipe culvert were placed.

The total cost of the work was $687.54, or $0.099 per square yard.

Fair Haven, Vt. (No. 3).—Work was begun September 15, 1913, on a gravel road extending north from Fair Haven toward West Castleton at the point known as Scotch Hill. It was completed on October 15, 1913, with three days lost on account of bad weather. The adjacent land is hilly, and the natural soil is clay from station 0 to 6 and sandy loam from station 6 to 12+20.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,220 feet. The maximum grade was reduced from 7 to 5 per cent. The maximum cut was 2 feet and the maximum fill was 1.8 feet. The material for the telford foundation, which extended for 400 feet of the clay portion, was obtained from stone walls. The gravel surfacing came from banks along the road and was laid 21 feet in width, a total area of 2,847 square yards.

One 18-inch corrugated-iron pipe culvert was laid.

The total cost of the work was $420.38, or $0.148 per square yard.

Fair Haven, Vt. (No. 4).—Work was begun October 18, 1913, on a gravel road extending northwest from Fair Haven toward Benson, beginning at a 12-foot iron bridge 3 miles north of Fair Haven. It was completed on November 7, 1913, with one day lost on account of rain. The adjacent land is hilly and the natural soil is clay.

The road was graded 26 feet wide in both cuts and fills for a distance of 578 feet. The maximum cut was 1 foot and the maximum fill was 1 foot. The maximum grade of 5 per cent on the old road was reduced to 4 per cent on the new road. A surface of bank gravel was laid 21 feet in width, making an area of 1,349 square yards.

The total cost of the work was $368.66, or $0.273 per square yard.

HOLDEN, VT. (No. 1).—Work was begun August 10, 1913, on a gravel section extending west from Holden on the Saw Mill Hill Road toward Grangerville. It was completed on September 15, 1913, with four days lost from various causes. The adjacent land is very hilly and the natural soil is clay and hardpan.

The road was graded 25 feet wide in both cuts and fills for a distance of 751 feet. The maximum cut was 2 feet and the maximum fill was 3.7 feet. The maximum grade of 13.5 per cent was reduced to 8.5 per cent. This was sidehill work, necessitating the construction of a retaining wall the entire length. The gutters were paved and guard rail erected. The road was surfaced 20 feet wide with bank gravel, making an area of 1,669 square yards.

One 18-inch corrugated-iron pipe culvert was placed and one 5 by 4 foot masonry culvert lengthened.

The total cost of the work was $641.80, or $0.384 per square yard.

HOLDEN, VT. (No. 2).—Work of improving the road extending northeast from Grangerville toward Holden was begun on September 20, 1913, and completed September 25, 1913. The adjacent land is hilly.

The work consisted in resurfacing with bank gravel 330 feet of old road to a width of 20 feet, making 733 square yards.

The cost of the work was $41.75, or $0.057 per square yard.

HUBBARDTON, VT.—Work was begun August 20, 1913, on a gravel road starting 3 miles north of Hubbardton Post Office at Beebe Pond and extending toward Sudbury. It was completed on October 31, 1913, with five days lost on account of various causes. The adjacent land is hilly and the natural soil is clay loam.

The road was graded 26 feet wide in both cuts and fills for a total distance of 759 feet. The maximum cut was 4 feet, the maximum fill 3 feet, and the grade of 9 per cent was reduced to 6 per cent. Considerable rock excavation was necessary and steam drills were employed. A heavy riprap wall was built almost the entire length and a guard rail erected.

Two 12-inch corrugated-iron pipe culverts were placed.

A surface of gravel was laid 21 feet in width, making an area of 1,771 square yards.

The total cost of the work was $1,139.55, or $0.643 per square yard.

HYDEVILLE, VT.—Work was begun on a gravel road extending west from Hydeville toward Fair Haven on August 10, 1913, and completed on September 11, 1913. Three days were lost on account of rain.

The road was graded 26 feet wide in both cuts and fills for a total distance of 1,634 feet. The maximum cut was 1 foot and the maximum fill 2.5 feet. Retaining walls were built to hold the fill and probably half of the excavation was rock. The maximum grade was reduced from 4 to 2.3 per cent. Gravel was obtained from banks nearby, and surfaced 21 feet in width, making 3,812 square yards.

Two 18-inch iron pipe culverts were laid, and 510 feet of 4-inch tile drain was placed under the north ditch line for subdrainage.

The total cost of the work was $1,039.77, or $0.272 per square yard.

IRA, VT.—Work was begun August 18, 1913, on a road extending northeast from Ira toward West Rutland, starting 3 miles northeast of Ira Church. It was completed on October 30, 1913, with a loss of five days from various causes.

This road parallels a stream which formerly washed out the road every spring. The channel of the stream was cleared of large bowlders and trees and a retaining wall was constructed. A 2 foot fill running the entire length of the work was then made of stone from old walls. This rock was carefully chinked with small stone and covered with gravel.

The road was graded 26 feet wide in both cuts and fills for a distance of 660 feet. The maximum fill was 3 feet and the maximum grade of 2 per cent was reduced to 1 per cent. A bank gravel surfacing was laid 21 feet wide, making an area of 1,540 square yards.

Two 2 by 3 foot masonry culverts with concrete tops were laid; also one 18-inch corrugated-iron pipe culvert.

The total cost of the work was $1,406.85, or $0.913 per square yard.

LAKE ST. CATHERINE, VT. (No. 1).—Work was begun August 1, 1913, on a gravel road starting at the iron bridge at the south end of Lake St. Catherine and extending north and then east toward Wells. It was completed on October 1, 1913, with a delay of four days on account of bad weather. The adjacent land is hilly and the natural soil from station 0 to 35 is sandy loam. The balance of the way is gravel.

The road was graded 26 feet wide in both cuts and fills for a distance of 4,673 feet. The maximum cut was 4.2 feet, the maximum fill 3.8 feet, and the maximum grade was reduced from 7 to 5.2 per cent.

A gravel surface 21 feet wide, making an area of 10,903 square yards, was laid, with a maximum haul of 1,500 feet for half the road. The gravel for the other half was obtained from banks alongside the road.

Three hundred feet of tile drain was constructed, two masonry culverts lengthened, one masonry culvert built, and five cast-iron pipe culverts laid.

The total cost of the work, including culverts, was $950.70, or $0.087 per square yard.

LAKE ST. CATHERINE, VT. (No. 2).—Work was begun June 1, 1913, on a gravel road beginning at the north line of the town of Wells and extending south toward Poultney, paralleling the lake. It was completed on September 10, 1913, with a delay of 10 days from various causes. The adjacent land is very hilly on the east, with the lake on the west. The natural soil is soft shale and clay.

The road was graded 24 feet wide in both cuts and fills for a distance of 3,364 feet. The maximum cut was 5.7 feet, the maximum fill 6 feet, and the maximum grade was reduced from 10 to 4 per cent on the new road. The shale rock was practically all picked by hand, being too soft to blast. Bank gravel, which was hauled about 1 mile, was laid for a width of 18 feet on the road, making an area of 6,728 square yards.

Stone retaining walls were built; also one 4 by 4 foot concrete box culvert. Three 18-inch corrugated-iron pipe culverts were placed.

The total cost of the work, including culverts, was $2,720.46, or $0.404 per square yard.

MENDON, VT. (No. 1).—Work was begun on a gravel section extending east from Mendon toward Sherburne on Mountain Road on August 20, 1913, and completed September 25, 1913. Five days were lost from various causes. The adjacent land is hilly and the soil a sandy loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 446 feet. The maximum cut was 0.5 foot and the maximum fill 1 foot. A surface of gravel was laid 21 feet wide, making an area of 1,041 square yards. The gravel was hauled about 2½ miles.

One 18-inch corrugated-iron pipe culvert was built.

The total cost of the work was $414.12, or $0.398 per square yard.

MENDON, VT. (No. 2).—Work was begun on a gravel section extending from a point one-half mile east of Mendon Post Office toward Sherburne on the Mountain Road on October 1, 1913, and completed October 31, 1913. The adjacent land is hilly and the natural soil is sandy loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,071 feet. The maximum cut was 1 foot, the maximum fill 0.5 foot, and the grade of 4 per cent on the old road was reduced on the new road to 3 per cent. The gravel was hauled from a point 2 miles distant and laid on the road 21 feet wide, a total area of 2,499 square yards.

One 18-inch corrugated-iron pipe culvert was laid.

The total cost of the work was $389.57, or $0.156 per square yard.

MIDDLETOWN SPRINGS, VT. (No. 1).—Work was begun August 15, 1913, on a gravel road extending west from Middletown Springs toward Poultney. It was completed on September 8, 1913, with three days lost on account of bad weather. The adjacent land is rolling and the natural soil is a sandy loam.

The road was graded 26 feet wide in both cuts and fills for a length of 627 feet. Gravel was hauled 3 miles for the surfacing and placed on the road to a width of 21 feet, or a total area of 1,463 square yards.

Two corrugated-iron pipe culverts were placed and one masonry culvert was lengthened.

The total cost of the work was $543.85, or $0.371 per square yard.

MIDDLETOWN SPRINGS, VT. (No. 2).—Work was begun September 10, 1913, on a gravel road 2¾ miles from Middletown Springs and extending west toward Poultney. It was completed October 4, 1913, with a delay of two days on account of bad weather. The adjacent land is hilly and the natural soil is sandy loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 396 feet. Gravel, which was hauled 3¾ miles, was laid on the road 21 feet wide, or a total of 924 square yards.

One masonry culvert was lengthened and one 18-inch corrugated-iron pipe culvert laid.

The total cost of the work was $132.63, or $0.143 per square yard.

NORTH PAWLET, VT.—Work was begun on a gravel road extending northwest from Spanktown toward Pawlet on October 1, 1913, and completed October 18, 1913, with a loss of one day on account of bad weather. The adjacent land is hilly.

The grade of the old road was not changed. The work consisted of blasting out shale rock to form the ditches and widening the road to 26 feet in both cuts and fills for a distance of 495 feet. It was then surfaced with bank gravel 21 feet wide, making an area of 1,155 square yards.

The total cost of the work was $134.30, or $0.116 per square yard.

PITTSFIELD, VT.—Work was begun September 1, 1913, on a gravel road north of Pittsfield extending from the Stockbridge town line toward Stony Brook Station. It was completed on October 15, 1913, with two days lost on account of rain. The adjacent land is hilly and the natural soil on the first half of the road is sand, while the last half of the road is clay.

The road was graded 26 feet wide in both cuts and fills for a distance of 594 feet. The maximum cut was 4 feet and the maximum fill 4 feet. The maximum grade of 11 per cent was reduced to 8 per cent. A telford base was laid for 60 feet. A surface of bank gravel 21 feet wide was laid, making an area of 1,386 square yards.

One 16-inch corrugated-iron pipe culvert was laid, and 320 feet of 6-inch tile drain was placed under the east ditch line through the cut.

The total cost of the work was $765.34, or $0.552 per square yard.

POULTNEY, VT.—Work was begun August 10, 1913, on a gravel road paralleling Lake St. Catherine and extending south from Poultney toward Wells. It was completed October 8, 1913, with three days lost on account of rain. The adjacent land is hilly and the natural soil is gravelly loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 2,393 feet. The maximum cut was 3.5 feet, the maximum fill was 2.8 feet, and the maximum grade was reduced from 4 to 2 per cent. Considerable grubbing and clearing was necessary in widening the road, and the excavated material was used for surfacing 21 feet in width, making an area of 5,583 square yards. The road was newly located for a distance of 400 feet.

Five corrugated-iron pipe culverts, ranging in size from 12 to 24 inches, were placed.

The total cost of the work, including drainage structures, was $1,427.36, or $0.255 per square yard.

PROCTOR, VT. (No. 1).—Work was begun on a gravel road extending north from Proctor toward Pittsford on June 1, 1913, and completed on August 1, 1913. Three days were lost on account of bad weather. The adjacent land is hilly and the natural soil is a sandy loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 3,201 feet. The maximum cut was 3.7 feet, the maximum fill was 2.9 feet, and the old maximum grade of 8 per cent was reduced to 6 per cent. A gravel surface was laid 21 feet wide, making a total of 7,469 square yards.

Three 18-inch and two 24-inch corrugated-iron pipe culverts were placed and approximately 275 linear feet of telford base was laid.

The total cost of the work, including culverts, was $2,035.38, or $0.272 per square yard.

PROCTOR, VT. (No. 2).—Work was begun on a gravel road extending east from Proctor toward Pittsford Mills on August 4, 1913, and completed on September 1, 1913. Rain delayed the work for two days. The adjacent land is hilly and the natural soil a sandy loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 710 feet. The maximum cut was 1.8 feet, the maximum fill was 1.2 feet, and the old maximum grade of 3 per cent was reduced to 2 per cent. Gravel was obtained close at hand and laid on the road 21 feet wide, or a total area of 1,656 square yards.

Two 18-inch and one 12-inch corrugated-iron pipe culverts were placed.

The total cost of the work, including culverts, was $221.21, or $0.133 per square yard.

RUTLAND CITY, VT.—Work was begun August 20, 1913, on a gravel road extending north from the south city line of Rutland toward Dorris Bridge. The road was entirely within the city limits and was completed on October 30, 1913, with a loss of three days on account of bad weather. The adjacent land is rolling on the west and level on the east side. The natural soil is sandy loam.

The road was shaped by a road machine 30 feet wide in both cuts and fills for a distance of 5,199 feet. Practically no grading was necessary. The road was surfaced with gravel 24 feet wide, making an area of 13,864 square yards. This gravel, which was hauled 3 miles, was compacted with a 10-ton roller.

Three 18-inch corrugated-iron pipe culverts were laid.

The total cost of the work, including culverts, was $3,874.47, or $0.279 per square yard.

RUTLAND, VT. (No. 1).—Work was begun August 1, 1913, on resurfacing with gravel a road extending north from the city line of Rutland toward Mill Village. It was completed August 10, 1913.

The road was surfaced with bank gravel for a width of 21 feet and a distance of 825 feet, making an area of 1,925 square yards.

The total cost of the work was $292.54, or $0.152 per square yard.

RUTLAND, VT. (No. 2).—Work was begun August 15, 1913, on a gravel section beginning at the south city line of Rutland on the Creek Road and extending south through Rutland Township to the Clarendon town line. Four days were lost on account of bad weather and it was completed on October 18, 1913. The adjacent land is rolling and the natural soil a sandy loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 3,399 feet. The maximum cut was 1.8 feet, the maximum fill 3 feet, and the maximum grade was reduced from 3 to 1.5 per cent. The road was surfaced with bank gravel 21 feet in width, making an area of 7,931 square yards. A guard rail was erected along all the embankment.

One 6 by 4 foot, one 5 by 4 foot, and one 2 by 3 foot culvert were built of masonry and concrete, and one 18-inch and one 12-inch corrugated-iron pipe culvert were laid.

The total cost of the work, including culverts, was $2,796.42, or $0.352 per square yard.

SHERBURNE, VT.—Work was begun August 20, 1913, on a gravel section extending east of Mendon toward Sherburne, at practically the highest point on the Mountain Road. It was completed on October 21, 1913, with three days lost on account of rain. The adjacent land is very hilly and the natural soil is clay loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 850 feet. The maximum cut was 4 feet, the maximum fill 3.4 feet, and the maximum grade of 15 per cent was reduced to 11 per cent. Gravel obtained during the grading was placed on the road to a width of 21 feet, or a total area of 1,983 square yards. Stone retaining walls were built at several places.

One 18-inch and one 24-inch corrugated-iron pipe culvert were laid.

The total cost of the work, including culverts, was $813.92, or $0.411 per square yard.

SHREWSBURY, VT. (No. 1).—Work was begun on a gravel road about midway between Shrewsbury and North Shrewsbury on June 6, 1913, and completed July 3, 1913. The adjacent land is hilly and the natural soil is clay and rock.

The road was graded 25 feet wide in both cuts and fills for a distance of 495 feet. The maximum cut was 3 feet, the maximum fill 3.9 feet, and the maximum grade of 12.8 per cent was reduced to 7 per cent. A surface of bank gravel was laid 20 feet in width, making an area of 1,100 square yards.

One 24-inch corrugated-iron pipe culvert was laid.

The total cost of the work, including culvert, was $272.34, or $0.248 per square yard.

SHREWSBURY, VT. (No. 2).—Work was begun on a gravel road extending west from Shrewsbury toward East Clarendon on September 15, 1913, and completed October 28, 1913. Three days were lost on account of bad weather. The adjacent land is hilly and the natural soil is clay.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,023 feet. The maximum cut was 2 feet, the maximum fill 4.1 feet, and the maximum grade was reduced from 8 to 6 per cent on the new road. The road was surfaced with bank gravel 21 feet wide, making an area of 2,387 square yards.

One 12-inch and one 18-inch corrugated-iron pipe culvert were laid and one 2 by 2 foot masonry culvert was lengthened.

The total cost of the work, including culverts, was $394.30, or $0.165 per square yard.

SPANKTOWN, VT.—Work was begun on a gravel road extending from Spanktown northwest toward North Pawlet on August 12, 1913, and completed on September 28, 1913. Two days were lost on account of rain. The adjacent land is rolling and the natural soil is clay loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,650 feet. The maximum fill was 0.8 foot.

Telford foundation was laid for 1,000 feet. A surface of gravel 21 feet wide, making an area of 3,850 square yards, was laid in two courses. The bottom layer was obtained from a creek bed nearby and the top coat was of bank gravel.

One 15-inch corrugated-iron pipe culvert was laid; also, one 2 by 2 foot and one 2 by 3 foot masonry culvert.

The total cost of the work was $694.25, or $0.180 per square yard.

SUDBURY, VT.—Work was begun August 8, 1913, on a gravel section running west from Brandon toward Jones's store on Cooks Hill Road and completed on October 15, 1913. Four days were lost on account of rainy weather. The adjacent land is hilly and the natural soil is loam, running to gravel loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 850 feet. The maximum cut was 3.8 feet, the maximum fill 2.6 feet. The grading work was rather heavy and the maximum grade was reduced from 12 per cent to 8 per cent. The road was surfaced with gravel obtained from the cuts and laid to a width of 21 feet, or a total area of 1,983 square yards.

Two 12-inch and one 18-inch corrugated-iron pipe culverts were laid and one 2 by 2 foot masonry culvert lengthened.

The total cost of the work, including culverts, was $888.10, or $0.447 per square yard.

TINMOUTH, VT. (No. 1).—Work was begun October 15, 1913, resurfacing with gravel the road beginning 1,500 feet east of Tinmouth church and extending east toward Wallingford. It was completed October 30, 1913, with one day lost on account of bad weather.

The road was surfaced 18 feet wide for a distance of 825 feet, making a total surfaced area of 1,650 square yards. The bank gravel used was hauled one-half mile.

The total cost of the work was $86.60, or $0.052 per square yard.

TINMOUTH, VT. (No. 2).—Work was begun August 1, 1913, on a gravel road beginning at the creamery in Tinmouth village and extending east toward Wallingford. It was completed on September 20, 1913, with a delay of two days on account of bad weather. The adjacent land is hilly and the natural soil a sandy loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,155 feet. The maximum cut was 3.8 feet, the maximum fill 2 feet, and the maximum grade was reduced from 11.5 to 7.5 per cent. Bank gravel surfacing 21 feet in width was laid, making a total surfaced area of 2,695 square yards.

One 3 by 4 foot masonry culvert was lengthened and one 24-inch corrugated-iron pipe culvert laid.

The total cost of the work, including culverts, was $962.59, or $0.357 per square yard.

WALLINGFORD, VT. (No. 1).—Work was begun on a gravel road in the village of Wallingford, extending north toward Rutland, on July 5, 1913. It was completed on July 31, 1913, with one day lost on account of bad weather. The adjacent land is rolling and the natural soil is loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,122 feet. The maximum fill was 3 feet and the maximum grade was reduced from 2 to 0.8 per cent on the new road. The road was surfaced 21 feet wide with bank gravel, making an area of 2,618 square yards.

One 12-inch and one 18-inch corrugated-iron pipe culvert were placed.

The total cost of the work, including culverts, was $365.40, or $0.139 per square yard.

WALLINGFORD, VT. (No. 2).—Work was begun August 3, 1913, on a gravel road beginning one-half mile north of Wallingford in Marsh Woods and extending north toward Rutland. It was completed on August 20, 1913. The adjacent land is rolling and the soil is clay loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 549 feet. The maximum fill was 2 feet and the maximum grade of 2 per cent on the old road was reduced to 1 per cent on the new road. A telford base was laid of stone, which was hauled 2 miles, and this was surfaced with bank gravel which was hauled 2¼ miles. The width of surfacing was 21 feet, making an area of 1,281 square yards.

One 3 by 3 foot masonry culvert was built and one 2 by 3 foot culvert was lengthened.

The total cost of the work, including culverts, was $741.80, or $0.580 per square yard.

WALLINGFORD, VT. (No. 3).—Work was begun August 23, 1913, on a gravel section 1 mile north of South Wallingford on the Creek Road. It was completed on September 20, 1913, with a delay of two days because of rain. The adjacent land is hilly and the natural soil is partly sand and partly clay loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,500 feet. The maximum cut was 2.8 feet, the maximum fill 2.5 feet, and the maximum grade of 8 per cent on the old road was reduced to 6 per cent on the new road. This work was all rather heavy. The road was surfaced 21 feet wide, making an area of 3,500 square yards.

One 18-inch corrugated-iron pipe culvert was laid.

The total cost of the work, including culvert, was $855.05, or $0.244 per square yard.

WALLINGFORD, VT. (No. 4).—Work was begun on a gravel road extending west from Wallingford toward Tinmouth on September 22, 1913. It was completed on October 25, 1913, with a loss of two days on account of bad weather. The adjacent land is hilly and the natural soil is sand and loam.

The road was graded 26 feet wide in both cuts and fills for 1,089 feet. The maximum cut was 3 feet, the maximum fill 3 feet, and the maximum grade of

9 per cent was reduced to 6 per cent A short section of hemlock crib was built to hold the embankment. Bank gravel was used for surfacing and was placed 21 feet wide, or a total of 2,541 square yards.

One 24-inch corrugated-iron pipe culvert was laid.

The total cost of the work, including culvert, was $591.85, or $0.233 per square yard.

WALLINGFORD, VT. (No. 5).—Work was begun on a gravel road extending west from Wallingford toward Tinmouth on October 26, 1913, and completed on November 5, 1913. The adjacent land is hilly and the natural soil is clay.

The road was graded 25 feet wide in both cuts and fills for a distance of 660 feet. The maximum cut was 1 foot, the maximum fill 1.8 feet, and the maximum grade was reduced from 3 to 2 per cent. A gravel surface 20 feet wide, making an area of 1,466 square yards, was laid. The average haul was 200 feet.

The total cost of the work was $79.35, or $0.054 per square yard.

WEST PAWLET, VT.—Work was begun October 25, 1913, on a gravel road beginning at the Bennington County line south of West Pawlet and extending north toward Rupert. It was completed November 12, 1913, with a delay of four days on account of rain. The adjacent land is rolling and the natural soil clay loam.

The road was graded 26 feet wide in both cuts and fills for a length of 1,320 feet. The maximum cut was 0.5 foot, the maximum fill 0.8 foot. The maximum grade of 2 per cent on the old road was reduced to 1.5 per cent on the new road. A bank gravel surface was laid 21 feet wide, making an area of 3,080 square yards.

The total cost of the work was $370.52, or $0.120 per square yard.

WESTHAVEN, VT. (No. 1).—Work was begun August 15, 1913, at a point 6 miles northwest of Fair Haven, on a gravel road extending northwest toward Benson. It was completed on September 10, 1913, with one day lost on account of rain. The adjacent land is hilly and the natural soil is sandy loam from station 0 to 2 and clay from station 2 to 12+71.

The road was graded 26 feet wide in both cuts and fills for a distance of 1,271 feet. Only the road machine was used, since very little grading was necessary. A surface of gravel 21 feet wide was laid, making an area of 2,956 square yards.

The total cost of the work was $279.10, or $0.094 per square yard.

WESTHAVEN, VT. (No. 2).—Work was begun August 12, 1913, at a point 3 miles west of Westhaven, on a gravel section extending on the West Road toward Lake Champlain. It was completed on September 6, 1913, with a loss of two days on account of rain. The adjacent land is hilly and the natural soil is clay.

The road was graded 24 feet wide in both cuts and fills for a distance of 743 feet. The maximum cut was 1 foot, the maximum fill 1.5 feet, and the maximum grade on the old road was reduced from 3 to 2 per cent. A telford foundation was laid for a distance of 200 feet. Bank gravel was used for surfacing and placed 20 feet wide, or a total of 1,651 square yards.

One 2 by 2 foot masonry culvert was lengthened and one 12-inch corrugated-iron pipe culvert laid.

The total cost of the work, including culverts, was $276.46, or $0.176 per square yard.

West Rutland, Vt.—Work was begun September 20, 1913, on a gravel road starting 3½ miles west of West Rutland and extending toward Castleton. It was completed October 8, 1913, with a loss of two days on account of rain. The adjacent land is hilly and the natural soil is sandy loam.

The road was graded 26 feet wide in both cuts and fills for a distance of 528 feet. The maximum cut was 2 feet, the maximum fill 1.8 feet, and the maximum grade of 4 per cent on the old road was reduced to 3 per cent on the new road. A surface of bank gravel 21 feet wide was laid, making a surfaced area of 1,232 square yards.

One 3 by 3 foot masonry culvert was lengthened.

The total cost of the work, including culvert, was $265.83, or $0.215 per square yard.

EXPERIMENTAL ROAD WORK.

A portion of the special appropriation for experimental road improvement was used to resurface with limestone macadam the road known as the Rockville Pike, in Montgomery County, Md., and to then treat the surface with various bituminous materials in conjunction with gravel, trap-rock screenings, and limestone screenings. The resurfacing was begun March 15, 1913, and the surface treatment started on September 5, 1913. The work was completed and the road opened to the public on December 17, 1913. In addition to the Rockville Pike, a 1,500-foot section on Bradley Lane, east from the pike, was resurfaced with limestone. The land adjacent to the road is rolling and the natural soil is for the most part a mica clay.

The reports following describe the resurfacing as done under the four contracts into which the work was divided. For a detailed description of the bituminous surface treatments, which were carried out in seven distinct sections, see Department Bulletin No. 105, "Progress Report of Experiments in Dust Prevention and Road Preservation, 1913."

Limestone Macadam Resurfacing.

Contract No. 1, Rockville Pike, Md.—Work was begun March 15, 1913, on the road from station 61+20 to station 210 and was completed August 8, 1913, with a loss of eight days on account of bad weather. The old roadbed was loosened by spikes in the roller wheels and a 3-ton scarifier.

The old macadam was reshaped and a surface of macadam was laid for 14,460 feet, 15 feet wide, making 24,100 square yards. About 248.22 tons of No. 1 stone were used to fill depressions, after which 2,911.75 tons of No. 2 stone were spread 3 inches deep before compacted, and 1,164.31 tons of stone screenings used for a binder course. The stone was shipped on the cars and the haul from the cars to the road was 1¼ miles.

Ditches were dug to the extent of 20,923 linear feet.

The equipment consisted of three 10-ton steam rollers, one sprinkler wagon, grading machine, dump wagons, gasoline pumps, tanks, small tools, etc.

The road was built by contract for $11,638.14, which is at the rate of $0.483 per square yard. Labor cost $1.70 and teams $4.50 per day of eight hours.

CONTRACT No. 2, ROCKVILLE PIKE, MD.—Work was begun April 25, 1913, on the road from station 0+15 to 61+20, and completed June 17, 1913, with a loss of three days on account of bad weather. A surface of macadam was laid for 6,105 feet, 15 feet wide, making 10,175 square yards. The old macadam road was loosened with spikes in the roller wheels, and a 3-ton scarifier was then used to tear the surface apart.

About 58.35 tons of No. 1 stone were used to level depressions and reshape the old surface, after which No. 2 stone was spread 3 inches deep to the amount of 1,102.8 tons. This layer was then rolled, and about 1 inch of screenings, or 440.7 tons, was spread, watered, and rolled until the surface was completed with a crown of one-half inch to the foot. The crushed rock was hauled from the cars to the road, with an average haul of three-fourths of a mile.

Drainage structures were as follows: Sixteen feet of 8-inch clay pipe; 14 feet of 12-inch clay pipe; 76 feet of 10-inch corrugated pipe. Thirty-three feet of pipe were relaid.

The equipment consisted of two steam rollers, sprinkler wagon, 3-ton scarifier, road machine, gasoline pump, portable tank, and small tools. Labor cost $1.70 and teams $4.50 per 8-hour day. The total cost of the road was $5,753.36, which is at the rate of $0.565 per square yard for surfacing, or $0.339 per square yard for the full width.

The principal items of cost were as follows at contract prices: Completed shoulders, 1,000 linear feet, at $0.15 per linear foot, $150; ditches, 6,000 linear feet, at $0.04 per linear foot, $240; scarifying and shaping subgrade, 10,000 square yards, at $0.06 per square yard, $600; stone in place, No. 1 stone, 58.35 tons, at $2.90 per ton, $169.21; No. 2 stone, 1,102.8 tons, at $2.90 per ton, $3,198.12; No. 3 stone, 440.7 tons, at $2.90 per ton, $1,278.03; 12-inch clay pipe, 14 linear feet, at $0.75 per linear foot, $10.50; 8-inch clay pipe, 16 linear feet, at $0.50 per linear foot, $8; 10-inch corrugated-iron pipe, 76 linear feet, at $0.85 per linear foot, $64.60; drop inlets, at $15 each, $15; lowering drain 33 linear feet, at $0.30 per linear foot, $9.90; inlets into culverts, $10.

CONTRACT No. 3, ROCKVILLE PIKE, MD.—Work was begun June 30, 1913, on the road from station 210 to station 477+89 and completed October 16, 1913, with a loss of four days on account of bad weather. It is estimated about 2,779.1 cubic yards of material were moved in grading the road. The old surface was loosened with spikes in the roller wheels, and a 3-ton scarifier was then used.

A surface of macadam was laid for 26,814 feet, 15 feet wide, making 44,690 square yards. After about 146.95 tons of No. 1 stone were used to level depressions, about 6,377.45 tons of No. 2 stone were spread to a depth of 3½ inches before compacted. This surface was rolled, and 1,651.85 tons of screenings were applied to a depth of 1 inch before compacted, and the surface sprinkled and rolled to a finished surface having a crown of five-eighths inch to the foot. The stone used was a limestone whose binding and wearing qualities are considered good. The material was dumped in long piles from wagons and spread to proper thickness by means of shovels and rakes. It was shipped in on the cars, and the average haul from the cars to the road was 1¼ miles.

Drainage structures were constructed as follows: Station 211+00, 28 linear feet 15-inch corrugated-iron pipe culvert; station 246+00, 26 linear feet 10-inch clay pipe and side drain; station 323+00, 28 linear feet 10-inch corrugated-iron pipe and side drain; station 328+00, 28 linear feet 10-inch corrugated-iron pipe and side drain. End walls were constructed at all pipe ends to fit local conditions.

The equipment consisted of four steam rollers, sprinkler wagons, 3-ton scarifier, road grader, small tools, etc. Labor cost $1.60 and teams $4.80 per 8-hour day. The road was built by contract for $23,704.71, which is at the rate of $0.53 per square yard.

Contract No. 4, Bradley Lane, Md.—Work was begun August 4, 1913, on the section of road extending from Wisconsin Avenue toward Connecticut Avenue on Bradley Lane. It was completed September 30, 1913. The road was graded 16 feet in both cuts and fills for 1,530 feet. A surface of macadam was laid for 1,530 feet, 10 feet wide, making 1,700 square yards. The crushed rock was delivered on the cars and hauled to the road, with an average haul of three-eighths mile. The surface of the old macadam road was loosened with spikes in the roller wheels, and torn apart with a 3-ton scarifier. This surface was then reshaped and leveled with No. 1 stone, and rolled, after which 3 inches of No. 2 stone were spread and rolled. About 1 inch of binder course was then spread, watered, and rolled, and the road finished with a crown of one-half inch to the foot.

The road was built by contract for $1,285.72, which is at the rate of $0.756 per square yard. Labor cost $1.70 and teams $4.50 per day of eight hours.

POST-ROAD WORK.

Under the act of Congress of August 24, 1912, making appropriation for the Post Office Department for the fiscal year 1913, there was appropriated $500,000 for the improvement of roads used in rural delivery, in order to ascertain how such improvement would affect the amount of territory served by rural carriers, the increase in number of delivery days, etc. In short, the improvements were to be carried out in such manner as to indicate the relative saving to the Government in the operation of the Rural Delivery Service, and to the local inhabitants in the transportation of their products. The Secretary of Agriculture was appointed to cooperate with the Postmaster General and to furnish the supervision for the construction work, which is being done through the Office of Public Roads. Under the act the local authorities pay not less than two-thirds of the cost of the improvement, and the Federal Government the remaining one-third. A detailed report, containing description and cost data of the work, will be published in a joint report made to Congress by the Secretary of Agriculture and the Postmaster General upon the completion of the work, which comprises the following 17 projects:

Lauderdale County, Ala., 30 miles of earth road;

Boone and Story Counties, Iowa, 51 miles of earth road;

Dubuque County, Iowa, 20 miles of gravel road;

Bath and Montgomery Counties, Ky., 11 miles of macadam road;

Montgomery County, Md., 5.4 miles of macadam road;

Cumberland County, Me., 21 miles of bituminous macadam road;

Leflore County, Miss., 24 miles of gravel road;
McDowell County, N. C., 16 miles of earth road;
Davie, Forsyth, and Iredell Counties, N. C., 48 miles of sand-clay and topsoil road;
Licking and Muskingum Counties, Ohio, 24 miles of concrete road;
Jackson County, Oreg., 51.4 miles of earth road;
Aiken County, S. C., 27.3 miles of sand-clay and topsoil road;
Loudon County, Tenn., 6.4 miles of macadam road;
Montgomery County, Tenn., 7.6 miles of macadam road;
Bexar, Comal, Travis, Hays, and Guadalupe Counties, Tex., 71.6 miles of gravel road;
Fairfax County, Va., 12.3 miles of gravel road;
Spotsylvania, Caroline, and Hanover Counties, Va., 38.2 miles of sand-clay and topsoil road.

BRIDGE WORK.

BRIDGES AND CULVERTS ON POST ROADS.

On the post roads typical designs of culverts and bridges prepared by the office were built wherever suitable for the location, and they are described in the reports of the post roads. In cases where typical designs did not fit the locations, special designs were made in accordance with surveys of the sites, as follows: Alabama, 2; Iowa, 2; Mississippi, 5; Tennessee, 3; Texas, 1; Virginia, 3.

PREPARATION OF PLANS, BRIDGE INSPECTIONS, ETC.

Typical designs were prepared for I-beam bridges with wooden floors for spans from 12 feet to 40 feet, varying in length by 2 feet. Bridge sites were inspected and special designs prepared, as follows: California, 2; Indiana, 2; New Hampshire, 1; North Carolina, 12; South Carolina, 6; Tennessee, 1; Virginia, 1. Final inspections of the bridges referred to above were made in a number of cases for the benefit of local officials. In several cases designs prepared by State highway departments and bridge companies were examined and reports made. Concrete abutments for a steel bridge at Stanley, N. C., were erected under supervision of an office engineer.

WORK OF THE DIVISION OF NATIONAL PARK AND FOREST ROADS.

The Division of National Park and Forest Roads was formed on February 16, 1914, with T. Warren Allen as chief. Arrangements were made early in 1914 for cooperation between the Department of the Interior and the Department of Agriculture, also between the Forest Service and the Office of Public Roads, for the purpose of bringing about the wisest possible expenditure of available funds for road building and maintenance in certain of the National Parks and Forests.

These arrangements provide that when the assistance of a highway engineer for any of the National Parks or Forests is desired, the assignment of such an engineer will be requested of the Office of Public Roads, and such engineer will be assigned by said office whenever it is practicable to do so. The salaries of such engineers are paid from funds of the Office of Public Roads, and their expenses from funds of the Department of the Interior when the cooperative work is within National Parks, and from funds of the Forest Service when the work is within National Forests. All work of construction is paid for from funds of the Department of the Interior or the Forest Service.

WORK DONE IN NATIONAL FORESTS.

In conformity with the agreements made, representatives of the office were placed in five of the Forest Service Districts and in three of the National Parks about the 1st of June, 1914. The men who were placed in the Forest Service Districts spent the first few months in learning conditions and particularly in getting acquainted with the road projects by making field inspections. In some cases, where the importance of the project warranted it, reconnaissance surveys were made. With the information thus obtained, together with data assembled from reports of forest supervisors, lists were made of the most important of the projects in each State, and these lists, showing the projects in the order of their importance, were transmitted through the district foresters to the Forester for his approval. As soon as possible after the approval of the lists, surveys were begun and carried to completion. In practically all of the districts surveys have been made of the projects which will be put under construction during 1915, and plans, estimates, and specifications are being prepared. A small amount of earth road construction was done up to January 1, 1915, but in most cases attention was confined to preparatory work to insure that an orderly progress of the work would be followed out.

SURVEY WORK.

In preparation for construction work, which is described later, the following survey work was done:

COCHETOPA FOREST, COLO.—*Cochetopa Pass Road.*—Nine and one-half miles of location survey was made and stakes driven for the construction work at a cost of $682.21.

ROUTT FOREST, COLO.—*Rabbit Ear Road.*—Eleven and one-half miles of location survey was made, plans prepared, and estimates begun at a cost of $786.76.

UNCOMPAHGRE FOREST, COLO.—*Alpine Road.*—Four miles of location survey was made at a cost of $328.82.

BIG HORN FOREST, WYO.—*Big Horn to Hazleton Road.*—Fifteen and three-tenths miles of location survey was made and work on plans begun at a cost of $816.86.

PALISADE AND TETON FORESTS, WYO.—*Teton Pass Road.*—Eleven and one-tenth miles of location survey was made at a total cost of $531.75.

PALISADE FOREST, IDAHO—*Teton Pass Road.*—Two and three-tenths miles of location survey was made at a total cost of $67.30.

PALISADE FOREST, IDAHO—*Victor Irwin Pine Creek Road.*—Eleven and four-tenths miles of location survey was made at a total cost of $294.48.

RUBY FOREST, NEV.—*Secret Pass Road.*—Four and six-tenths miles of location survey was made at a total cost of $265.45.

DIXIE FOREST, UTAH.—*Modena to St. George Road.*—Fifteen and three-tenths miles of location survey was made at a total cost of $615.92.

SEVIER FOREST, UTAH.—*Panguitch to Tropic Road.*—Nine and five-tenths miles of preliminary survey was made at a total cost of $353.68.

TONTO FOREST, ARIZ.—*Salt River to Pleasant Valley Road.*—Twenty-four and eight-tenths miles of location survey was made and preparation of plans started, at a total cost of $2,044.17.

SITGREAVES FOREST, ARIZ.—*Snowflake to Pinetop Road.*—Twenty miles of location survey was made at a total cost of $772.75.

DATIL AND GILA FORESTS, N. MEX.—*Reserve to Alma Road.*—Forty-four and nine-tenths miles of location survey was made and preparation of plans started, at a total cost of $1,646.43.

JEMEZ AND PECOS FORESTS, N. MEX.—*Espanola to Cuba Road.*—Twelve and four-tenths miles of location survey was made and preparation of plans begun at a total cost of $950.45.

CARSON FOREST, N. MEX.—*Questa to Elizabethtown Road.*—Six and three-tenths miles of location survey was made at a total cost of $410.35.

CALIFORNIA.—Reconnaissance surveys covering a total distance of 209 miles were made in 12 of the forests, at a total cost of $2,216.21.

CONSTRUCTION WORK.

A résumé of the construction work done follows, all of which was done by force account under supervision of this office.

HARNEY FOREST, S. DAK.—Two miles of the Sylvan Lake section of the Deadwood-Hot Springs Road were built at a cost of $4,790.10. This is an earth-surface road, on which was done 10,330 linear feet of clearing and grubbing, mostly 50 feet wide, 5,630 cubic yards of earth excavation, and 634 cubic yards of rock excavation. Nineteen culverts were put in. There is also included in the above expenditure $1,747.45 to complete an adjoining section 1,510 feet in length, work on which was begun in 1913.

COCHETOPA FOREST, COLO.—Nine and one-half miles of the Cochetopa Pass Road were built at a cost of $12,339.69. This is an earth-surface road, on which was done 21,157 linear feet of clearing and grubbing, 66 feet wide, 38,270 cubic yards of earth excavation, and 1,800 cubic yards of rock excavation. Fifty-two culverts were put in.

SAN ISABEL FOREST, COLO.—Eleven hundred and thirty-five linear feet of the North Hardscrabble Road were built at a cost of $1,824.59. It is an earth road with excavation all in solid rock. The work done was in completion of a section begun in 1913.

ROUTT FOREST, COLO.—Three miles of the Rabbit Ear Road were built at a cost of $6,893.11. This is an earth-surface road, and the above work completes the project begun in 1913.

MONTEZUMA FOREST, COLO.—One mile of the Dolores River Road was built at a cost of $887.92. This is an earth road on which there was done 3,700 linear feet of clearing and grubbing, 2,560 cubic yards of earth excavation, 371 cubic yards of rock excavation, and 80 linear feet of corduroy. One log bridge and six log culverts were put in. This work is in extension of a 3-mile section built last year.

BRIDGER FOREST, WYO.—A log truss bridge of three 35-foot spans was built across the Green River at a cost of $60.85. Piers and abutments were of logs with filling of stone.

PAYETTE FOREST, IDAHO.—*Payette River, South Fork Road.*—Two and four-tenths miles of road were built at a total cost of $6,230.74. The road is of earth on which was done 3,294 cubic yards of earth excavation, 6,202 cubic yards of rock excavation, and 42 cubic yards of loose rock excavation. To facilitate rock excavation, there was used on this road an air compressor and a plug drill, driven by a gasoline engine.

IDAHO FOREST, IDAHO.—*Warren State Road.*—This is an earth-surface road on which for 2.1 miles general repair work was done, costing $856.98.

UINTA (NEBO) FOREST, UTAH.—*Santaquin Road.*—This is an earth-surface road on which for 3 miles general repair work was done, costing $545.64. There were 3 miles of clearing and grubbing, 1,050 cubic yards of earth excavation, and 128 cubic yards of rock excavation. Three log culverts were built.

WASATCH FOREST, UTAH.—*Kamas to Stockmore Road.*—This road is of earth and was constructed for a length of 1.7 miles at a total cost of $1,772.86. There were done 1.7 miles of clearing and grubbing and 4,092 cubic yards of earth excavation. Three log bridges were built.

POWELL FOREST, UTAH.—*Escalante to Winder Road.*—An earth-surface road was constructed for a length of 4 miles at a total cost of $4,845.15.

KAIBAB FOREST, ARIZ.—*Grand Canyon Highway.*—An earth-surface road was constructed for a length of 1.9 miles at a total cost of $1,829.14.

RUBY FOREST, NEV.—*Toyn Canyon Road.*—The work on this road consisted in making the existing road from 2 to 4 feet wider at a total cost of $524.49.

RUBY FOREST, NEV.—*Harrison Canyon Road.*—An earth-surface road was constructed for a distance of three-tenths of a mile at a total cost of $380.85. There was done 0.3 mile of clearing and grubbing for a width of 24 feet, 2,300 cubic yards of earth excavation, 78 cubic yards of rock excavation, and 200 linear feet of ditching.

HUMBOLDT FOREST, NEV.—*Gold Creek to McDonald Road.*—General repair work was done on 6 miles of existing earth road at a total cost of $391. In addition to the grading done six log culverts and one log bridge were built.

HUMBOLDT FOREST, NEV.—*Gold Creek to Jarbidge Road.*—General repair work was done on 1 mile of existing earth road at a total cost of $54.

HUMBOLDT FOREST, NEV.—*Mountain City to Aura Road.*—General repair work was done on one-quarter mile of earth-surface road at a total cost of $201.

KLAMATH FOREST, CAL.—*Seiad Trail.*—Three miles of trail were built up Seiad Creek to connect with a trail built in the Crater Forest in Oregon. The total cost was $801.

TRINITY FOREST, CAL.—*Trinity River Road.*—A contract was made for $410 to clear off approximately 1,500 cubic yards of earth from slides on the portion of the road built last year.

Work was also done in the States of Oregon and Washington.
In addition to the above minor repair work was done as follows:

COCHETOPA FOREST, COLO.—Cochetopa Pass Road, $112.87.
BIG HORN FOREST, WYO.—Buffalo to Hazleton Road, $25.22.
ROUTT FOREST, COLO.—Rabbitt Ear Road, $56.63.

WORK DONE IN NATIONAL PARKS.

Representatives of the office were placed in Sequoia, Yosemite, and Glacier National Parks, and survey work was carried on in each one of these with the idea of continuing the work until surveys have been made and plans and estimates prepared for a complete road system for each of these parks.

In the Yosemite survey work has been completed on a road from the westerly boundary of the park near the railroad terminal at El Portal easterly up the valley of the Merced River, through the village of Yosemite to the top of the Nevada Falls, a distance of about 21 miles. Plans and estimates for this road are being prepared in 5-mile sections, and they have been completed for section No. 1, which begins at the aforesaid westerly boundary line. The cost of this work to December 31, 1914, was $3,131.23, or $149.10 per mile.

A topographical survey was made of the floor of the valley to show contours at intervals of 2 feet. This survey was made for the purpose of establishing a new village site and working up a development scheme for this portion. The area covered is about 3 square miles, and the cost $332.60, or $110.87 per square mile.

In the Sequoia Park a survey was made from the Giant Forest by way of Wolverton Creek, the Marble Fork of the Kaweah River, and Willow and Cahoon meadows to the north boundary of the park near J. O. Pass, a distance of about 10 miles. The plans and estimates for this road are being prepared in sections. Section No. 1 extends from the Giant Forest to the crossing of the Marble Fork. In addition to this 13.5 miles of level line were run over the park entrance road. The total cost of the work done in Sequoia Park is $2,233.60.

In Glacier Park a survey was made for a road from the mouth of Fish Creek at Lake McDonald northwesterly to McGee's meadow on the road along the easterly side of the North Fork of the Flathead River, a distance of about 5 miles. Plans and estimates are being prepared for this road. A survey was also begun for a road from the mouth of Fish Creek northerly along the westerly side of Lake McDonald, but the work was interrupted by winter weather when about 4 miles of the survey had been completed. This survey along the lake will be extended northerly to the head of the lake and from there northerly to Waterton Lake and along it to the northerly boundary of the park, which is also the boundary line between the United States and Canada. The total cost of the work done in Glacier Park to January 1, 1915, is $1,700.99.

WORK OF DIVISION OF MAINTENANCE.

The maintenance work of the office was separated and a division formed on February 16, 1914, with E. W. James as chief. At that time some experimental maintenance for purposes of securing cost data was being conducted on 8 miles of road in Alexandria County, Va., under a memorandum of agreement with the county authorities, and plans were being considered for maintaining the experimental roads built by the office in Montgomery County, Md.

On the organization of the division the following lines of work were planned. They are all continuous projects within the limits noted.

I. STUDY OF THE DETAILS OF ROAD MAINTENANCE AS CARRIED OUT BY STATE AUTHORITIES IN REPRESENTATIVE STATES.

The work under this head will enable the office to draw from the experience of the most advanced and efficient highway organizations in the country the results of their experiments and endeavors, and to extend this information by correspondence and actual demonstration to those communities where improved roads have been built at large cost and are deteriorating more or less rapidly, because of lack of organization, information, and skilled supervision in matters pertaining to road maintenance. The studies are being made in a number of States having well-organized highway departments, such as Massachusetts, New Hampshire, Connecticut, New York. This work has so far been limited to short studies in the first and third divisions of Massachusetts, the first division of New York, the ninth and part of the sixth division of New Hampshire.

Preliminary inspections were made covering general organization of maintenance force and the system of roads under maintenance. Some general details of average costs and general resurfacing methods were included. The smaller and more intimate details of the work will require personal studies in the field with construction gangs for a considerable period of time.

II. STUDY OF THE DETAILS OF COUNTY MAINTENANCE IN SELECTED COUNTIES.

To extend maintenance investigations into regions which have no State organization but still depend entirely on the county system of road administration certain counties are to be studied which have constructed improved roads on a large scale. No work has yet been done in this line, but plans are being made to do work in Allegheny County, Pa.; Montgomery County, Ala.; Hines County, Miss.; Hillsboro and Duval Counties, Fla. The Division of Road Economics will cover details of organization in county road maintenance and to that extent cooperate with this division.

III. INAUGURATION OF MAINTENANCE ON POST ROADS CONSTRUCTED UNDER ACT OF CONGRESS OF AUGUST 24, 1912.

On the maintenance of all post roads constructed under the act of August 24, 1912, the office furnishes advice and where possible exercises supervision.

Maintenance under a county engineer is now systematic on the Virginia post road in Spotsylvania County and on the completed part of the Ohio post road. This work involves the keeping of accurate costs to determine the annual cost of maintenance per mile. Plans are being made to extend this maintenance to post roads in Maine, Tennessee, Texas, and Alabama.

IV. SUPERVISION OF MAINTENANCE ON A ROAD FROM WASHINGTON, D. C., TO ATLANTA, GA.

Demonstration road maintenance is being conducted on the Washington-Atlanta Highway from Petersburg, Va., southward. The purpose of this work is principally to demonstrate maintenance methods and the value of road maintenance in increasing not only the number of days in the year that an earth or sand-clay road can be kept in good condition, but the extent to which the wear of gravel, macadam, and other types may be counteracted by ordinary methods of maintenance. As the work continues, the demonstration is developing the following facts, which are here enumerated without comment. It is expected that further work will provide more corroborative data for very valuable observations with reference to local road administration.

1. County boards, although having full administrative authority, appear not to attach to their official action in road matters the importance or legal effect which it should have.

2. County boards do not generally have sufficient accounting control of road funds to know what is available for any particular project—where funds have been, or where existing balances are to be, expended.

3. Lack of any systematic practice in handling road funds among most counties makes it very difficult to carry out over even a single year any persistent maintenance policy, because funds officially obligated for maintenance purposes are not protected against sporadic and irregular draughts for miscellaneous purposes. The greatest likelihood consequently exists everywhere that there will be no balance in the maintenance fund in the last half or third of the year, although only a part of the fund allotted may have been spent.

4. Local labor available for maintenance work is made dissatisfied by the constant, unintelligent, and unfavorable criticism of those using the road.

5. Maintenance continuing over a period of years—the ultimate indispensable condition of effective maintenance—is jeopardized by the lack of accounting control that prevents spending next year's current income in this year.

6. The lack of skilled supervision in construction and the effect of this in increasing the cost or in making effective maintenance impossibly expensive are everywhere seen.

7. The county authorities are commonly opposed to following suggestions for maintenance that involve tying up road funds in any way, such as purchasing materials in advance to store along the road for making repairs or maintaining the road surface.

All of the above matters are quite apart from the customary expected difficulties encountered in practical details of maintenance, and the elimination of many of these perplexing matters can apparently only follow some educational propaganda and a general enlightenment of county voters and officials. These troubles are not all found in any one county, but no county is entirely free from all.

These matters will be made the basis for special study, with a view to suggesting detailed, effective remedies so far as they can be applied under existing conditions and to promoting a better understanding of the imperative needs of maintenance to conserve the huge investment of public funds being made annually in county road construction.

A total of 681.8 miles is now under the supervision of this office. This is about 81.2 per cent of the distance from Petersburg to Atlanta and 69.1 per cent of the total distance from Washington to Atlanta on the selected route. A large number of companion photographs have been taken showing the condition of this road at the time the Government supervision commenced, and again after improvement.

Table I shows the distribution of mileage in the several counties, the mileage under patrol squads or gangs, and the amounts expended for maintenance and construction. All the work is cooperative and the counties which are participating in the plan first signified their concurrence in the project by adopting and recording a resolution establishing the legal status of supervision by the Government. The counties then made application on a form provided by the office. When these were properly executed they were then filed in the Washington office.

TABLE I.—*Maintenance and construction funds expended, mileage, etc., Washington-Atlanta Highway.*

No.	County.	State.	Total mileage in county.	Mileage under Government supervision.	Construction funds expended to Dec. 31, 1914.	Allotted for maintenance.	Spent for maintenance to Dec. 31, 1914.	Mileage on which construction has been done.	Mileage under patrol.	Mileage under squad.
1	Dinwiddie	Virginia	28.1	28.1	$1,156.89	$2,010.00	$1,376.52	2.0	28.0	
2	Brunswick	do	30.0	30.0	1,428.00	1,050.00	362.03			30.0
3	Mecklenburg	do	44.0	29.0	300.00	575.00	340.50	2.0		27.0
4	Granville	North Carolina	35.0	35.0	8,368.58	2,100.00	975.88	4.0	35.0	
5	Durham	do	23.0	23.0	7,398.19	2,000.00	900.57	1.0	23.0	
6	Wake	do	41.0	41.0	5,457.57	3,000.00	844.37	6.0	41.0	
7	Johnston	do	33.0	17.0	1,068.59	1,500.00	313.90	2.0	15.0	[1] 15.0
8	Harnett	do	10.0	10.0	2,400.00	500.00	66.65	4.0		10.0
9	Cumberland	North Carolina, north half.	21.0	18.0	1,375.00	1,600.00	983.34	1.0		18.0
		North Carolina, south half.	12.1	12.1		(2)	136.00		12.1	
10	Hoke	North Carolina	26.2	26.2	2,046.95	1,600.00	200.00	16.0		26.2
11	Moore	do	22.4	20.7	267.00	1,655.00	746.75	3.0	20.7	
12	Montgomery	do	1.6	1.6					1.6	
13	Richmond	do	32.8	32.3		1,600.00	467.50	20.0	32.3	
14	Marlboro	South Carolina	9.1							
15	Chesterfield	do	35.3	32.7	8,333.23	1,700.00		32.7		
16	Kershaw	do	38.0							
17	Richland	do	18.5	15.3		650.00	1,010.50			15.3
18	Lexington	do	31.6	29.0	724.46	1,040.00	626.16	3.0	29.0	[1] 10.5
19	Saluda	do	4.3							
20	Aiken	do	40.2	38.2		1,850.00	691.50		25.2	13.0
21	Columbia	Georgia	8.0		659.40					
22	McDuffie	do	28.5	28.5	1,992.39	1,300.00		9.0		
23	Warren	do	17.7	17.7	2,067.90	1,045.00		12.0		
24	Wilkes	do	28.8	28.8	6,230.00	1,300.00		4.0		
25	Taliaferro	do	12.6	12.6	2,134.40	600.00		12.5		
26	Oglethorpe	do	19.4	19.4		900.00				
27	Greene	do	24.1	24.1	1,819.75	1,300.00		2.5		
28	Clarke	do	18.3	18.3	1,289.50	1,000.00				
29	Oconee	do	6.8							
30	Walton	do	27.9	27.9	1,505.00	1,000.00		2.5		
31	Morgan	do	20.1	20.1	479.60	1,000.00		0.5		
32	Newton	do	16.6		4,950.00			7.0		
33	Rockdale	do	9.4							
34	Gwinnett	do	16.6		376.20			2.0		
35	Dekalb	do	28.8	28.8	9,227.60	1,250.00		4.5		
36	Fulton	do	3.3							
37	Richmond	do	16.4	16.4	2,729.75	950.00		0.5		
	Total		840.5	681.8	75,785.95	36,075.00	10,042.17	153.7	262.9	139.5

[1] Both patrol and squads. [2] As needed.

The work of maintenance is being done by patrolmen and gangs. Patrolmen have sections that vary in length from 6 to 29 miles. The average in the northern section is 12.9 miles, and in the central section 10.8 miles. Some of these patrol sections are too long, but funds were not available to provide any more men.

The usual maintenance work on earth and sand-clay roads includes:

(*a*) Dragging persistently at every available opportunity;

(*b*) Using the grading machine when necessary;

(*c*) Filling depressions;

(*d*) Adding sand or clay as required;

(*e*) Removing all trash, tin cans, nails, old iron, bottles, etc., that accumulate in somewhat astonishing quantities;

(*f*) Replacing broken floor boards in culverts and bridges;

(*g*) Keeping culverts open;

(*h*) Clearing ditches and shoulders;

(*i*) Cutting grass and weeds;
(*j*) Trimming brush and trees at curves;
(*k*) Harrowing and dragging rough or irregular sections;
(*l*) Painting guard rails and culvert heads; and
(*m*) Posting roads.

Records are being kept of locality of expenditures, so far as possible, by using the county financial records supplemented by private notes and the report cards of the patrolmen. A statement of the cost per mile of work on each patrol section will be possible in a later report, but at the present time only one or two counties have spent more than 55 per cent of the allotted funds.

The condition of the road under maintenance has been good during the entire period up to December 23. At about that time the range of temperature in North Carolina and Virginia became such as to cause alternate freezing and thawing, and heavy rains caused swollen streams throughout the entire territory. These conditions at once showed the weak places in the roads. Drainage is prevalently insufficient. This is, of course, largely a structural defect that ordinary maintenance can not cure. Especially has the need of subdrainage been demonstrated. This is almost invariably neglected in the region traversed by this road.

In many sections it has become apparent that the common earth road is not adequate to accommodate the prevailing traffic. During the best weather and during ordinary summer rains no trouble develops, but average protracted rains cause the roads to break up faster and deeper than maintenance can repair them under the continuous stream of traffic.

Since many of the roads along the route were subjects, not for maintenance, but for actual construction, it was necessary, in the preliminary estimates, to include the cost of minimum improvements in all cases where such work was necessary in order to get the roads ready for maintenance. This has led to a great deal of new construction and much reconstruction and repair in each State along the line. The nature of this work has ranged all the way from minor bridge and culvert repairs to the expenditure of bond issues on systematic new construction. The table shows the amounts expended in the various counties in construction under the general supervision of the Government engineers detailed to the project. One assistant has been almost constantly in the northern section giving undivided attention to this work. It is not necessary to itemize the various improvements made, further than that they include all lines of highway work except hard surfacing. Bridges have been relocated and rebuilt or renewed; new roads laid out and graded; earth roads have been surfaced with sand-clay or topsoil; grade crossings have been eliminated by overpasses, underpasses, or relocations; roads have been straightened and widened; culverts have been located, built, and enlarged. The total amount expended in such work up to December, 1914, was $75,785.95, and about $125,000 was available in the fall for continued work. The local financial conditions resulting from the state of the cotton market during the autumn may considerably reduce this figure before it is spent.

V. SUPERVISION OF MAINTENANCE IN ALEXANDRIA COUNTY, VA., UNDER EXISTING AGREEMENT, AND ON THE UNITED STATES EXPERIMENTAL ROADS IN MONTGOMERY COUNTY, MD.

The maintenance of the experimental roads in Montgomery County, Md., is reported in detail in Department Bulletin No. 257. A system of columnar accounts was devised and used to control costs on each of the several experimental sections. The purpose of this work is to demonstrate comparative costs of maintenance on a large variety of surface treatments.

The maintenance of earth roads in Alexandria County, Va., for the purpose of obtaining cost data was started under the Division of Construction on December 30, 1911, and was transferred to this division in February, 1914. Under the present memorandum of agreement it will be continued until June 30, 1915. There have been some changes in the route, and for purposes of better distributing the costs and disclosing any differences that might exist in the general demands of traffic on the different parts of the road it was divided into the following sections:

	Miles.
1. Mount Vernon Road from Hume Station, on the Washington-Virginia Railway, to Nauck over the Old Factory Road	1.7
2. Seminary road from county line to Columbia Pike over the Glebe Road	3.15
3. Hatfield or Fort Myers Road from Hatfield Station, on the Falls Church electric line, to Arlington post office, on the Columbia Turnpike	1.11
4. Balston Road from Columbia Turnpike northward	.51
Total	6.47

Table II shows the entire cost of the work up to January 1, 1915.

TABLE II.—*Cost of maintenance work on 6.5 miles of earth and gravel road in Alexandria County, Va.*

Sections.	Work on surface.	Work on slopes.	Work on ditches.	Miscellaneous and general.	Gravel used.	Total.
					Cu. yds.	
1	$76.91	$34.25	$39.25	$90.07	19.5	$240.48
2	192.04	74.25	219.75	256.26	45.75	742.30
3	55.00	21.75	16.25	53.51	12.00	146.51
4	66.05	14.25	26.75	67.16	22.75	174.21
Total for July 1, 1913, to Dec. 31, 1914.	390.00	144.50	302.00	467.00		1,303.50
Fiscal year 1912	153.44	61.78	169.88	49.89		434.99
Fiscal year 1913	283.68	89.28	198.00	185.04		756.00
Total to date	827.12	295.56	669.88	701.93		2,494.49

A total of 922.66 miles has been dragged once at a total cost, included in the surfacing charges, of $180.01, which is at the rate of 19.5 cents per mile dragged. In dragging, the average operation has been three and one-half trips over the section.

The cost of maintenance per mile has been $141.46 on section 1; $235.33 on section 2; $131.99 on section 3; $341.59 on section 4, or a weighted average of $201.47 per mile for the whole road.

During the entire year 1914 these roads continued to improve in cross section and condition. Section 2 was ditched over nearly its entire length and much ditching was done along parts of other sections. The county grading machine was borrowed and operated at Government expense for four days in the early fall. Up to December 23, 1914, the time of last inspection, the roads remained in excellent condition and at that time were much better than in May and June.

This experimental work serves to secure cost of dragging, to determine the cost of maintenance that fully meets the wear of traffic on earth and cheap gravel roads, and to demonstrate that earth roads can actually be improved by a regular system of maintenance.

VI. SUPERVISION OF MAINTENANCE ON SOME TYPICAL ROAD IN COUNTIES THAT HAVE RECENTLY CONSTRUCTED A SYSTEM OF HIGHWAYS.

This project is to encourage and promote systematic, intelligent, effective maintenance methods and to assist in devising a scheme for maintenance administration in the county. Owing to the wide distribution of the available roads, this project can not be advanced until a larger organization is developed.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 285

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER. October 22, 1915

THE NORTHERN HARDWOOD FOREST: ITS COMPOSITION, GROWTH, AND MANAGEMENT.

By E. H. FROTHINGHAM, *Forest Examiner*.

CONTENTS.

INTRODUCTION.

The great hardwood forests of eastern North America separate naturally into two divisions—northern and southern—the one relatively simple, the other varied and rich in composition. What distinguishes the northern from the southern hardwood forest is the presence of yellow birch, white pine, and hemlock and the absence of yellow poplar, red gum, sycamore, and many other southern species. The geographical extent of the northern hardwood forest, in fact, practically coincides with the range of yellow birch (fig. 1, p. 2). It centers about the region in which the white pine lumbering industry was developed.

Early logging in the northern hardwood forests took chiefly the white pine, little hardwood timber being felled except in clearing for settlement. As time went on and demands increased, the cullings extended to spruce, hemlock, and even the more valuable hardwoods. The poorest of the species are now so valuable that stands are often cut clean, and even the tops, branches, and larger undergrowth utilized. There are many reasons why the consumption of hardwoods may be expected to decrease, yet the qualities of these slow-growing trees are so obvious and their woods are so admirably adapted to such a variety of uses that the problem of perpetuating at least a reasonable supply is one of public concern.

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It is the aim of this bulletin to outline the extent, general characteristics, and economic importance of the northern hardwood forest; to describe briefly the silvicultural features of the principal species; and to point out the methods of managing hardwood stands which appear best calculated to furnish a continuous supply of these useful woods. There are also given, in the Appendix, a series of volume tables for northern hardwoods for use in estimating the quantity of standing timber.

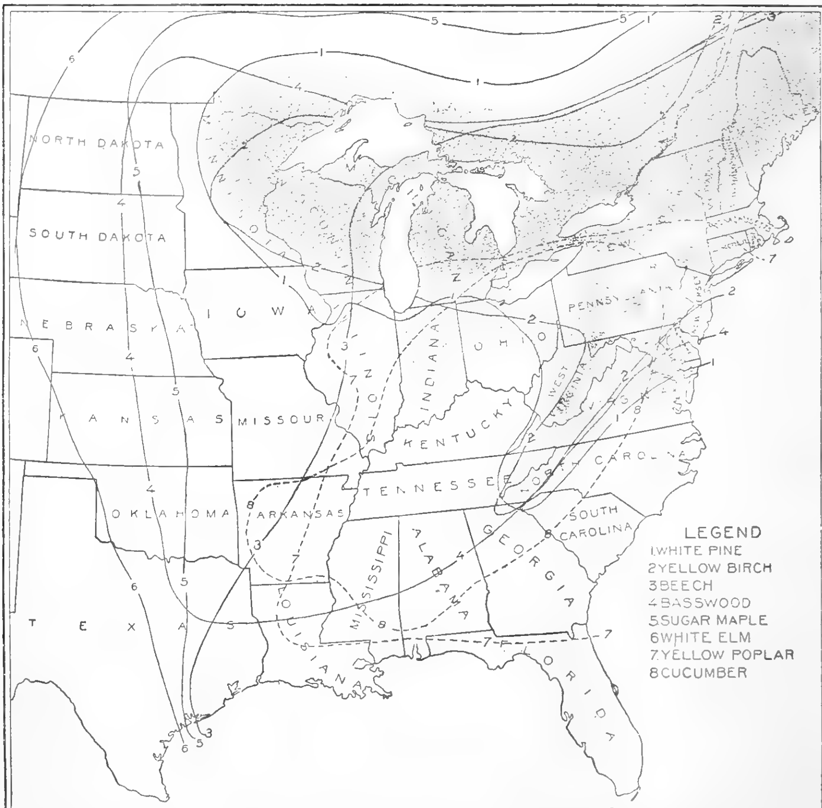

FIG. 1.—Distribution of the northern hardwoods. (The heavy shading represents the region in which the northern hardwoods characterize large areas of forest. The light shading indicates the region of transition from the typical northern to the southern hardwood forest. The numbered lines are the ranges of the species named in the legend. The broken lines are the range limits of two southern hardwoods whose presence largely determines the southward extension of the northern forest. Prepared by Wm. H. Lamb.)

THE NORTHERN HARDWOOD FOREST.

The hardwood forest which is considered in this bulletin occupies the fresh, well-drained, fertile soils of the northern pine region. Its more characteristic hardwoods are sugar maple [1] and yellow birch.

[1] The closely related black maple is not distinguished from sugar maple in this bulletin. Both are commonly referred to as "hard" or "rock" maple.

The term "northern hardwoods" will be used for all stands in this region in which one (or more) of the characteristic species listed on page 7 predominates; for though the type possesses a general uniformity of composition sufficient to distinguish it from other important northern forest types, it varies greatly in different regions.

There are two hardwood forest types that are not considered in the bulletin, although the species which belong to them are often found scattered through the northern hardwood forests. These are the type of the dry sandy plains, in which the chief hardwoods are oaks of various kinds, mixed with hickories and in the east with chestnut, and the type of the swampy places, in which the characteristic hardwoods are black ash, red and silver maples, willows, and alders. The swamp type is not of great extent or importance, and the other type is so much more characteristic of the South that it might be considered only a northern extension of a southern type.

GEOGRAPHICAL EXTENT.

The northern hardwood forest (fig. 1) is found in greater or less abundance within the drainage systems of the St. Lawrence, the Great Lakes, and the upper Mississippi, as far south as southern Minnesota; throughout northern New England, and southward along the northern and southern Appalachian Mountain ranges to extreme northern Georgia. In the North it merges into the spruce and fir and the aspen and birch forests of Canada. Along its southern and lower altitudinal borders it shades into the great "central hardwoods" forest of the Ohio and Mississippi Valleys. In the West it gradually gives place to the prairie of the Great Plains region. On the uplands the "oak openings" supplant it in large measure, until these, too, give way to the prairie. Just how large an area is occupied by northern hardwoods is difficult to estimate. It probably amounts to over 50,000,000 acres, nearly half of which is in the Lake States. The decrease in the total forest area of the Lake States and the northeast—once practically equal to the entire land area—to 60 per cent in New England, 43 per cent in Michigan and Wisconsin, and 35 per cent in New York and Pennsylvania,[1] has undoubtedly been greatest in the softwood forest.

TOPOGRAPHY AND CLIMATE.

Topographically the northern hardwood region separates into two very distinct parts—the eastern mountain ranges and the rolling, glaciated land about the Great Lakes.

The eastern mountain ranges extend from southern Canada southwest to northern Alabama and Georgia. The climatic conditions suitable for the best growth of the northern hardwoods prevail at minimum elevations of from 500 feet in northern New England to 1,000 feet in southern New England and the Adirondacks and 3,500

[1] Forest Service Circular 166, "Timber Supply of the United States," by R. S. Kellogg.

feet in the southern ranges. Above these altitudes the hardwoods give place in large measure to spruce and fir. On northerly slopes the climate suitable for northern hardwoods is often at several hundred feet lower altitude than on southerly exposures.

The soils in the northern hardwood zone are, as a rule, loamy sands, the result of the decay of granite, quartzites, and siliceous gneisses. In the eastern mountains they are partly glacial and partly residual in origin, thin, and of low agricultural value. In the Lake States and through much of the northeast they were deposited by the glaciers in moraines and glacial hills or laid down in beds of varying thickness by glacial streams. Here the hardwoods occupy, for the most part, the water-assorted loams and clays or the unassorted morainal tills, rich in clay, but also thrive on light, sandy soils in localities subject to prevailing moist winds, as in western lower Michigan. In the Appalachians, south of the limit to which the glaciers extended, the soils result entirely from the decomposition of the native rocks. Where schists prevail, fertile loams are the products of decomposition, and these may reach some depth in the coves and broader valleys.

The climatic factors which determine the distribution of forests are moisture and temperature. These differ in relative importance according to the nature of the region. In temperate semiarid regions the determining factor is moisture; in temperate humid regions it is temperature. The northern forest region is distinctly humid, and the composition of the forests is therefore influenced chiefly by temperature. Its western limits, however, are fixed chiefly by moisture factors.

The growing season is approximately five months, from May to September, inclusive.[1] The duration of the season varies within the region, and is shortest in the north and at high altitudes. This factor has undoubtedly a large influence upon the composition of the northern hardwood forests, which is not so much a matter of the sensitiveness of the species to extremes of temperature as it is of optimum temperature.

How moisture and temperature affect the different species in the complexity of the forest environment is still so little known that no positive information can be given. The best that can be done is to compare the available climatic data from observation stations within the northern forest region with corresponding data from stations just outside. Table 1 accordingly gives the average monthly temperature and precipitation during the growing season for adjacent parts of the northern and southern hardwood regions. Similar data for April and October are also given, together with the annual precipitation and depth of snow.

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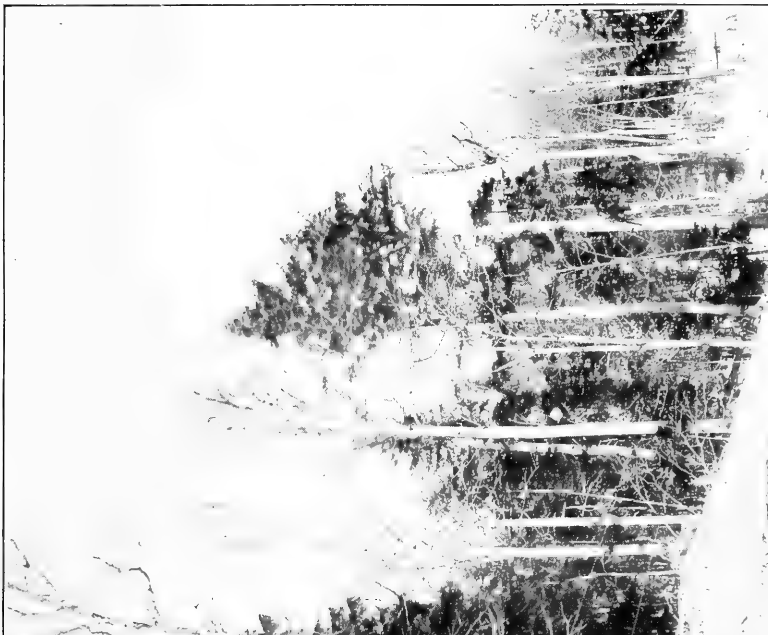
[1] Raphael Zon, "Meteorological Observations for Purposes of Botanical Geography, Agriculture, and Forestry," Dept. of Agriculture Monthly Weather Review, vol. 42, No. 4, April, 1914; map shows division of the United States on basis of periods of vegetative growth and rest.



CULLED FOREST OF NORTHERN HARDWOODS, SPRUCE, AND HEMLOCK IN THE ADIRONDACKS.

Spruce trees 10 inches and over breasthigh have been removed.

CUT-OVER HARDWOOD LAND IN NORTHERN WISCONSIN LOGGED DURING AN "OFF YEAR" FOR MAPLE LUMBER.

The best maple was taken but much good material was left standing. Lumbermen called this a "clean cutting."

TABLE 1.—*Temperature and precipitation* [1] *within the northern hardwoods and the northern edge of the southern hardwood regions. Based on data from United States Weather Bureau Bulletin Q (1906); observations extending over period of from 5 to 50 years.*

Geographical division and forest region.	Average monthly temperature.							Average temperature for the growing season.
	Apr.	Growing season.					Oct.	
		May.	June.	July.	Aug.	Sept.		
New England and the Adirondacks:	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
Northern hardwood	41	54	62	66	64	57	46	61
Southern hardwood	44	56	65	70	67	60	48	64
Alleghenies and Southern Appalachians:								
Northern hardwood	46	59	66	69	67	62	50	65
Southern hardwood	50	62	68	72	71	64	54	67
Lake States:								
Northern hardwood	41	53	63	68	64	57	45	61
Southern hardwood	47	58	67	72	70	62	50	66
General average:								
Northern hardwood	42	54	63	67	65	58	46	61
Southern hardwood	47	59	67	71	69	62	51	66

Geographical division and forest region.	Average precipitation.							Average total precipitation.		Average annual snowfall.
	Apr.	Growing season.					Oct.	Growing season.	Annual.	
		May.	June.	July.	Aug.	Sept.				
New England and the Adirondacks:	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Inches.*	*Inches.*	*Inches.*
Northern hardwood	2.4	3.3	3.9	4.4	4.1	3.7	3.3	19.4	42.8	96.1
Southern hardwood	2.9	3.5	3.8	4.1	3.8	3.5	3.6	18.7	44.8	78.1
Alleghenies and Southern Appalachians:										
Northern hardwood	3.4	4.1	5.6	4.9	4.7	3.6	3.8	22.9	49.2	58.5
Southern hardwood	3.1	3.9	4.6	4.7	3.5	3.1	2.5	19.8	41.8	32.4
Lake States:										
Northern hardwood	2.3	3.5	3.8	3.8	3.6	3.4	3.1	18.1	31.1	64.0
Southern hardwood	2.4	3.3	3.8	3.5	3.0	3.0	2.4	16.6	29.9	40.1
General average:										
Northern hardwood	2.5	3.6	4.2	4.2	4.0	3.5	3.3	19.0	38.4	75.5
Southern hardwood	2.9	3.6	4.1	4.2	3.4	3.2	2.8	18.5	39.2	48.4

[1] Monthly averages for the growing season—May to September, inclusive—and for April and October, with average annual precipitation and snowfall.

The stations and altitudes at which the observations were taken are as follows:

Station	Feet.
Northern hardwoods:	
New England—	
Mayfield, Me	1,000
Bethlehem, N. H	1,470
Stratford, N. H	950
Wells, Vt	1,000
Jacksonville, Vt	1,000
Saranac Lake, N. Y	1,620
Number Four, N. Y	1,571
Alleghenies and Southern Appalachians—	
Le Roy, Pa	1,400
State College, Pa	1,191
Terra Alta, W. Va	3,207
Linville, N. C	3,800
Lake States—	
Calumet, Mich	1,246
Escanaba, Mich	594
Grayling, Mich	1,147
Ivan, Mich.	
Koepenick, Wis	1,675
Medford, Wis	1,420
Grantsburg, Wis	1,095
Mount Iron, Minn	1,510
Sandy Lake Dam, Minn	1,229
Park Rapids, Minn	1,300
Southern hardwoods:	
Lewiston, Me	210
Concord, N. H	280
Rome, N. Y	450
Pittsburgh, Pa	757
Elkins, W. Va	1,920
Hot Springs, Va	2,195
Asheville, N. C	2,255
Lansing, Mich	881
Madison, Wis	974
St. Paul, Minn	758

COMPOSITION.

THE FOREST AS A WHOLE.

The species commonly found in the northern hardwood forest are separated in Table 2 according to their abundance and distribution; only approximately, however, because there are many subordinate variations which can not be shown. The list does not include several dwarf maples, thorn apples, mountain ash, etc., which are of little or no economic importance.

TABLE 2.—*Hardwoods and conifers grouped according to their prevalence in the northern hardwood forests.*[1]

Region.	Characteristic.	Locally characteristic.	Occasional.
Northeastern States	Yellow birch. Sugar maple. Beech. Red maple. Ironwood. Hemlock. White pine. Red spruce. Balsam fir.	Paper birch. Aspen. Large tooth aspen. Fire cherry. Black birch. Basswood. White elm. White ash. Silver maple. Red oak. White spruce.	Black ash. Slippery elm. Gray birch. Black cherry. Balm of Gilead. Norway pine. Black spruce. Tamarack. Arborvitæ.
Lake States	Sugar maple. Yellow birch. Basswood. White elm. Beech.[2] Ironwood. Hemlock. White pine.	Paper birch. Aspen. Large tooth aspen. Fire cherry. Cork elm. White ash. Red maple. Red oak.	Black ash. Slippery elm. Balm of Gilead. Black cherry. Black birch. Silver maple. White spruce. Black spruce. Balsam fir. Tamarack. Arborvitæ. Norway pine. Jack pine.

[1] In the transition zone between the northern and southern hardwood forest—especially in Pennsylvania and the southern Appalachians—yellow poplar, magnolia, sycamore, black and red gums, and other southern hardwoods not shown in the above list often appear in some abundance among the northern hardwoods.

[2] Beech is not found in Minnesota and only in extreme eastern Wisconsin.

Under the heading "Occasional" are included a number of species which are characteristic either of swamp or of dry-soil types, but are often found among the northern hardwoods as strays. Besides these there are a number of oaks, hickories, walnuts, pines, and birches which occasionally intrude, but being characteristic of other site conditions, can not be considered regular members of the northern hardwood forest. The great bulk of the forest consists of the species listed as "characteristic." The proportions of the species, as will be brought out more fully, vary greatly in different parts of the region. The "locally characteristic" species are found here and there, some rare or of small value, others abundant locally and of considerable importance. Some of these species, especially paper birch and the aspens, form distinct but transitory types on burned-over lands (Pl. VIII), but occur only as widely scattered individuals in old growth stands. They are light-foliaged trees, intolerant of shade, which shelter beneath their crowns the reproduction of maple, beech, hemlock, and other shade-tolerant and heavy-foliaged species. One generation of the intolerant trees is all that is possible under these conditions, for their seedlings can not live in the dense shade of the other undergrowth already started. Survivors of the original temporary stands, however, are often found in the hardwood forest, as well as isolated individuals which have sprung up among old timber where there are accidental openings in the crown cover. Most of the conifers, notably white pine and red spruce, also grow in well-marked types of their own, often in pure stands. Basswood and elm, on the other hand, rarely grow otherwise than as scattered individuals, except in Michigan and Wisconsin, where they sometimes form fully a third of the total stand.

About 15 species of hardwoods are common to the northern and southern forests, and 8 (birches, aspens, fire cherry, and black ash) are found only in the northern. Grouped according to geographical range, north and south, the trees of the northern hardwood forest, excluding a few of the less important, are as follows:

Range northern.	*Range northern and southern.*
Hardwoods:	Hardwoods:
Yellow birch.	Sugar (and black) maple.
Paper birch.	Red maple.
Gray birch.	Silver maple.
Aspen.	Black birch.
Large tooth aspen.	Beech.
Balm of Gilead.	Basswood.
Black ash.	White elm.
Fire cherry.	Slippery elm.
Conifers:	Cork elm.
Red spruce.	Ironwood.
White spruce.	White ash.
Black spruce.	Black cherry.
Balsam fir.	Red oak.
Hemlock.	
White pine.	
Norway pine.	
Jack pine.	
Tamarack.	
Arborvitæ.	

The northern forest with about 21 hardwoods is much simpler in composition than the southern, which contains fully 95 of local or general commercial value. It has been still further simplified by selective lumbering. Not only the white pine, spruce, and hemlock, but in many places the better hardwoods also, have been heavily cut, thus increasing the proportion of the less valuable kinds in the culled forests.

REGIONAL VARIATIONS.

The eastern part of the northern hardwood forest is characterized by the abundance and importance of red spruce and balsam fir. These extend south from Canada along the mountains of New England, the Adirondacks, and the southern Appalachians, at increasing elevations. The relatively pure spruce and fir forests occupy higher altitudes than the hardwood forest, but the two are freely intermixed through a broad but not definitely marked altitudinal zone. Though red spruce is the most common spruce associate of the hardwoods, white spruce is sometimes the more abundant locally. The spruce is largely replaced in the Alleghenies by hemlock; and here cucumber (*Magnolia acuminata* Linn.) and yellow poplar, prominent members of the southern hardwood forest, appear in small quantities among the northern hardwoods.

Like the spruce type, the transitory burned-land type of aspen and paper birch is more abundant and of greater perfection in northern New England than in the Lake States. Farther south it becomes less important; paper birch drops out in northern Pennsylvania, and the type loses its identity more and more through the inclusion of other species.

Of the characteristic northern hardwoods, sugar maple is probably the most abundant in the northeastern States at large. Yellow birch, however, is the most abundant in northern New England. It grows in forests of widely different composition, and shares to some extent the habits of paper birch, appearing on burns in small, pure, even-aged stands (Pl. X, fig. 1, and Pl. VII, fig. 2) or in mixed stands with paper birch and aspen, to which it adds an element of permanence. Spruce, maple, and beech, which thrive in the light shade cast by such stands, outlive the paper birch and aspen, and will eventually gain the ascendancy. In the old-growth forests, therefore, yellow birch is found in a great variety of mixtures with spruce, fir, beech, sugar and red maples, white pine, and hemlock, with scattered individuals or groups of other species, notably paper birch and aspen. The old-growth hardwoods in this region are usually very defective, the beech especially. The red maple is usually abundant only as a subordinate growth of little value.

Ash occurs sparsely in New England at low to moderate elevations. Black birch and black cherry become locally abundant in the mountains of southern Vermont and New Hampshire, the Adirondacks, Catskills, and farther south. The northern hardwood forest continues south at gradually increasing altitudes along the southern Appalachian Mountains, becoming more and more restricted to northerly slopes and cool valleys. This region properly belongs to the transition zone between the northern and southern hardwood

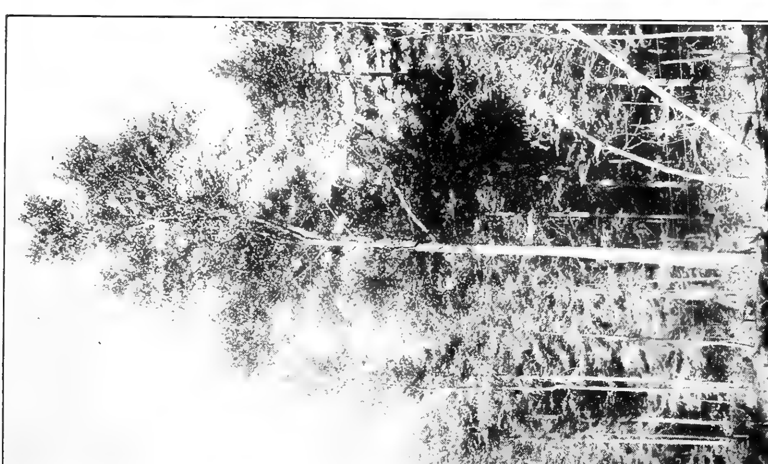


Fig. 1.—Beech.

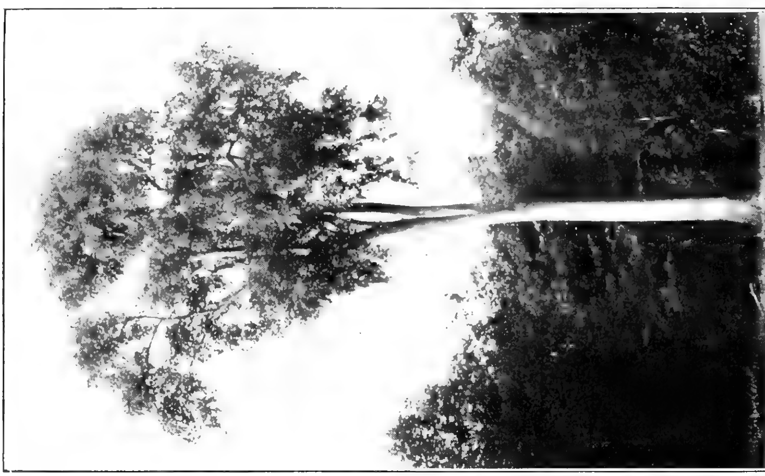


Fig. 2.—White Elm.

Fig. 3.—Sugar Maple.

TREE FORMS OF NORTHERN HARDWOODS IN THE FOREST.

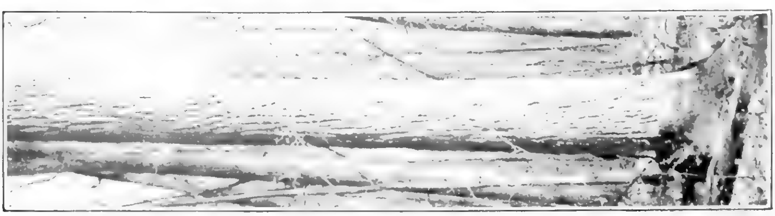


FIG. 1.—WHITE ELM.

FIG. 2.—SHORT-BODIED YELLOW BIRCH.

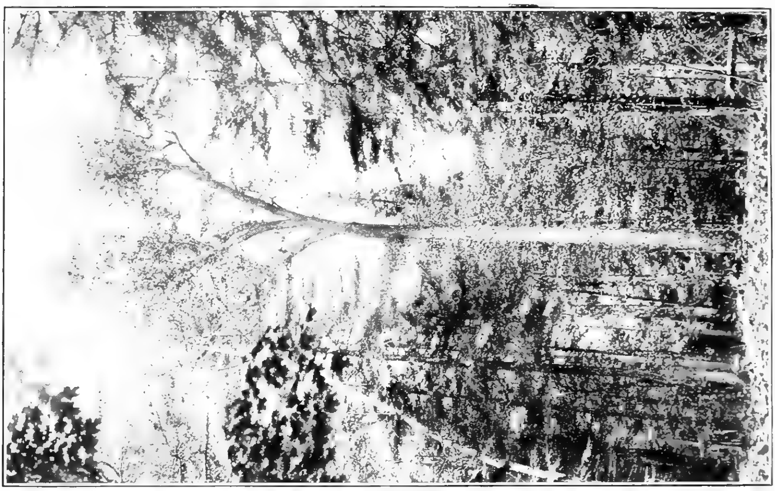


FIG. 3.—LONG-BODIED YELLOW BIRCH.

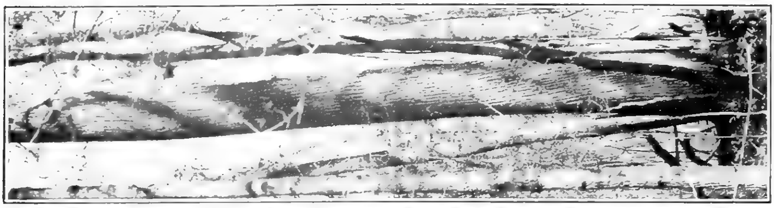


FIG. 4.—BASSWOOD.

TREE FORMS OF NORTHERN HARDWOODS IN THE FOREST.

regions. In the higher mountains spruce covers the peaks and ridges, especially on northerly slopes, and associates freely with the northern hardwoods along the lower edges of the spruce belt. White pine and hemlock also continue south along the Appalachians, and by mixing with the hardwoods help to maintain the characteristic structure of the northern forest.

Extensive pure stands of beech are found on ridges in southern North Carolina and farther north along the Blue Ridge. The commercial importance of the northern hardwoods is minimized, however, by the abundance of valuable southern timber trees like white oak and yellow poplar.

Elm and basswood as forest trees are more abundant in southern New England than in Maine and northern New Hampshire. These species appear at low altitudes and increase in quantity toward the west and south, their scarcity throughout the east being in marked contrast to the abundance in which they are found in the west. The great abundance of basswood and elm is perhaps the most striking characteristic of the northern hardwood forest in the Lake States. According to estimates compiled by the Bureau of Corporations,[1] basswood forms 12 per cent and elm 9 per cent of all the hardwoods in these States. Maple leads in amount with 35 per cent, birch comprises 24 per cent, beech 4 per cent, and ash 2 per cent of the total hardwood stand. Together these six species make up more than a third of the total stand, hardwoods and softwoods, in the Lake States. Table 3, arranged from a similar table in the Bureau of Corporations report, illustrates the relative importance of the northern hardwoods, individually and collectively, in the Lake States forests during 1910 (the year in which the data were gathered). The estimates do not include publicly owned timber, which, however, does not amount to a large proportion of the merchantable stand.

TABLE 3.—*Privately owned standing timber in the Lake States, by species.*[2]

Species.	Total.	Michigan.	Wisconsin.	Minnesota.
	Board feet.	*Board feet.*	*Board feet.*	*Board feet.*
Total	100,000,000,000	47,600,000,000	29,200,000,000	23,200,000,000
Conifers	58,100,000,000	22,200,000,000	17,100,000,000	18,800,000,000
Hardwoods	41,900,000,000	25,400,000,000	12,100,000,000	4,400,000,000
Maple	14,500,000,000	12,200,000,000	2,300,000,000	
Birch	10,100,000,000	5,100,000,000	4,300,000,000	700,000,000
Basswood	5,100,000,000	2,200,000,000	2,500,000,000	400,000,000
Elm	3,700,000,000	2,100,000,000	1,500,000,000	100,000,000
Beech	1,600,000,000	1,600,000,000		
Ash	1,000,000,000	600,000,000	300,000,000	100,000,000
Poplar (and balm of gilead)	2,000,000,000			2,000,000,000
Oak	700,000,000	200,000,000	300,000,000	200,000,000
Miscellaneous	3,200,000,000	1,400,000,000	900,000,000	900,000,000

[1] Report on the lumber industry, Pt. I, Standing timber.

[2] From Bureau of Corporations, Report on the lumber industry—Standing timber, 1913, p. 78.

Table 3 shows that in the Lake States, as in the East, yellow birch and sugar maple are the most abundant generally, the chief characteristics that distinguish this part of the northern hardwood forest from the northeastern part being the abundance and importance of basswood, elm, hemlock, and white pine, and the absence of red spruce. Here also, however, some spruce extends down from Canada, in this case white spruce being the more important, especially in Minnesota, and black spruce occurring seldom except in the swamps or "muskegs."

In Michigan the stand of sugar maple alone exceeds that of all the other northern hardwoods combined, and amounts to more than a quarter of the total hardwood and softwood stand. The maple in Michigan is of better quality than in many parts of New England, but in Wisconsin much of the maple is very defective (Pl. II). Maple is not abundant in Minnesota, and is as yet of small commercial value; in fact, the hardwoods as a whole are of relatively small importance in this State. Beech is found in Wisconsin only for a short distance inland from Lake Michigan. Yellow birch is especially abundant and important in Wisconsin, and in Minnesota it is the most abundant of the characteristic northern hardwoods. Black birch is found, but much less abundantly than in southern New England. There is more basswood than elm in Michigan; in Wisconsin they are nearly equal in quantity. "Poplar" (aspens) occupies considerable area in all three States, but by far the largest amount is found in Minnesota. In Michigan and Wisconsin the stands are for the most part too young to be of any commercial value.

FOREST RELATIONSHIPS AND THEIR EFFECT ON COMPOSITION.

There are two sets of factors which influence the success of trees in the natural forest, and which must be regarded in silviculture: Physical, including soil and climate, and physiological, including aggressiveness in reproduction, tolerance of shade, rate of growth, form, size, longevity, and resistance to injury and disease. To some extent these factors are interactive, and a deficiency in one or several may be offset by a marked superiority in some other. For instance, rapid growth may compensate for intolerance of shade, air moisture for soil poverty, abundance of seed for low fertility, and longevity and resistance to injury for intolerance and ineffective reproduction. It is therefore profitable to consider the factors more or less in combination. Those of tolerance and reproduction are generally the most important in determining the local distribution and abundance of the species.

Tolerance and reproduction.—Table 4 lists the important species in the northern hardwood forest in the approximate order of their shade tolerance, beginning with the least tolerant, and gives the characteristics of each which influence its reproduction inside and outside of the forest.

These characteristics are subject to variation. Tolerance, for example, is greater in seedlings than in old trees, in the south than in the north, and in fertile than in dry situations. The frequency of seed years and the fertility of the seed produced depend to a large extent on climatic factors, and the amount is influenced by these and by the light supply; even the annual seed bearers do not produce the same amount each year. The extent of seed distribution depends on the height and exposure of the crown, the buoyancy of the seed, and the strength and steadiness of the winds at seed time. Growth of both seedlings and sprouts is influenced by the length of the growing season, the fertility of the soil, and the humidity of the air. All of these variations, by affecting the aggressiveness of particular species in competition with others, modify the composition of the stand. The variations caused by physical factors (soil, precipitation, temperature, etc.), though they do have an influence during the youth of the stand, are active especially in determining the character of the old-growth forest, and are chiefly responsible for differences in its composition at different latitudes, longitudes, altitudes, and exposures. Those caused by physiological factors are especially active in the establishment and subsequent history of temporary stands.

The temporary stands formed by species aggressive outside the forest give way, after they have developed, to species which are aggressive inside the forest. A convenient classification might be based upon this difference in aggressiveness, the trees being called, respectively, extensive or intensive reproducers, according to whether they are more aggressive outside or inside the forest. The separation of the species into these classes would then be made on the basis of the last two columns of Table 4. Extensive reproducers are intolerant of shade, and are generally small, rapid-growing, short-lived, and light-foliaged, and have a tendency to form even-aged stands (Pl. VI). Intensive reproducers are tolerant in tendency, of slow growth and long life, and form uneven-aged stands with dense crown cover (Pl. V). To be sure, these characteristics exist among the different species in all degrees between the extremes, so that a hard and fast line can not be drawn between the extensive and intensive reproducers. Some species even are extensive under certain conditions and intensive under others. Nevertheless the divergent tendencies are perfectly evident and a scale can be drawn the extremes of which are almost exclusively extensive and intensive.

TABLE 4.—*Tolerance and reproduction of hardwoods and conifers in the northern hardwood types.*

Species in order of tolerance (approximately), beginning with the least tolerant.	Seed production.						Seedlings.		Sprouting capacity.	Aggressiveness in reproduction.	
	Periodicity.	Seed crops.		Dispersal.		Per cent fertility.[1]					
		Season.	Amount each seed year.	Extent.	Chief means.		Requirements for rapid growth.	Growth rate.		In the open.	In the forest.
Aspen	Annual	Spring	Immense	Very wide	Wind	Low	Very much light; cool, moist soil and air.	Rapid	Very effective.	Very high.	Very low.
Fire cherry	do	Summer	Large	do	Birds	Very high.	No shade	do	Effective	do	Do.
Gray birch	do	Fall	do	Wide	Wind	Moderate (probably).	do	do	Very effective.	do	Do.
Black cherry	do	Summer	do	Moderate	Birds	High	Much light	do	Effective	High	Low.
Paper birch	do	do	do	Wide	Wind	Rather low	Much light; cool, moist soil and air.	do	Very effective.	Very high.	Do.
White ash [2]	Not annual [3]	Fall	do	do	do	Moderate	Much light;[2] moist, fertile soil.	do	Effective from small stumps.	Moderate	Moderate.
White elm	Annual	Spring	do	do	do	do	Much light; moist air or soil.	do	Unimportant except in youth.	do	Low.
White pine	Not annual	Fall	do	Moderate	do	High	Light shade for first year or two; mineral soil.	Slow	Absent	High	Do.
Basswood	Annual	Early fall	Moderate	do	do	Moderate	Light shade; moist air.	Rapid	Very effective.	Moderate	Moderate.
Yellow birch	do	Fall	Large	Wide	do	do	Cool, moist air and soil; side shade.	Moderate	Effective from small stumps.	do	Do.
Black birch	do	do	do	do	do	Low	do	do	do	do	Do.
Red maple [4]	do	Spring	do	Moderate	do	Moderate	Moist soil and air	Rapid	do	do	Do.
Ironwood	do	Fall	Moderate	do	do	do	Moist air and soil; shade.	Moderate	(?)	Low	High.
Sugar maple	do	do	Large	do	do	do	Moist soil and air	Slow	Effective from small stumps.	Moderate	Do.
Beech	Not annual	do	Rather small	Restricted	Rodents	do	Warmth, humus, shade.	do	Ineffective	Very low	Moderate.
Red spruce	do	do	Large	Moderate	Wind	High	Cool, moist air, mineral soil.	Very slow.	Absent	Moderate	Do.
Hemlock	do	do	do	do	do	Moderate	Shade; moist air, humus soil.	do	do	Very low	High.

[1] Includes abortive seed produced and amount destroyed by insects and fungi while still on the tree. Basswood and beech, for example, lose much seed from these causes.
[2] As a seedling white ash is more tolerant than yellow birch, and will persist for years under fairly heavy shade.
[3] White ash bears some seed annually, but full crops only at intervals of several years.
[4] Red maple is decidedly less tolerant in swamps.

"INTENSIVE" ALL-AGED REPRODUCTION IN A VIRGIN FOREST OF SUGAR MAPLE, BEECH, BASSWOOD, AND HEMLOCK. ROSCOMMON COUNTY, MICH.

"EXTENSIVE" EVEN-AGED REPRODUCTION OF ASPEN AND FIRE CHERRY ON CUT AND BURNED OVER WHITE-PINE LAND IN WISCONSIN.

For the species in Table 4 such a scale is approximately as follows:

Most extensive:
1. Aspens.
2. Gray birch.
3. Paper birch.
4. Fire cherry.
5. Black cherry.
6. White pine.
7. Yellow birch.
8. Black birch.
9. White ash.

Most extensive—Continued.
10. White elm.
11. Red spruce.
12. Basswood.
13. Sugar maple.
14. Red maple.
15. Ironwood.
16. Hemlock.

Most intensive:
17. Beech.

Red spruce and yellow birch are examples of species which though in most respects intensive, are also extensive, under favorable conditions. Both often reproduce in even-aged second-growth stands on clearings, while the spruce, and to a less extent the birch, are able to start seedlings within the forest.

The extensive species are obvioulsy well adpated for quickly reclaiming burned or otherwise cleared land, and not for competition with intensive species. (Pl. VI.) Aspen and paper birch are rapidly displaced by maple, beech, or hemlock, or, in fact, any others of the "characteristic" species of the northern forest whose reproduction may happen to start beneath them.

The intensive reproducers hold their ground when once they have gained it; but they differ among themselves in aggressiveness and persistance. Sugar maple is the most generally aggressive reproducer throughout the characteristic beech-birch-maple type. This is undoubtedly due to its combined tolerance and seeding qualities. Beech, which is probably more tolerant, does not bear large seed crops annually, and much of the seed produced is destroyed by animals. Yellow birch, which does bear each year, is less tolerant than maple. Its light-winged seed are so widely dispersed, however, that many fall where the crown shade is light enough to permit the development of seedlings. These are adaptable to a great variety of seed-bed conditions, from sandy soils burned free of humus to duff-covered clay loams, and even moss-covered bowlders, decayed stumps, and logs. Yellow birch thus accomplishes through its reproductive aggressiveness often more than beech can accomplish through its extreme shade endurance. White elm and basswood both require much light for growth and especially for seed production. The elm seeds, with their surrounding wings, are light, thin disks, fitted to be distributed quite widely by the wind; the tree bears annually and abundantly. Basswood seeds are produced in less abundance, and at first glance seem poorly adapted for wind dispersal. They are suspended in clusters of as many as six large spherical fruits beneath a single bract, apparently insufficient in size for a long flight; but when the seed clusters fall the bract becomes an efficient helicopter, which, in a light breeze, may bear its load of seed a hundred yards or more. The seedlings of basswood and elm are able to endure moderate shade for 5 or 6 years, but seedlings of greater age are rare in the virgin forest except where the crown cover is broken.

Forest-grown beech, birch, and maple seedlings which receive but little light develop into extremely slender, whip-like saplings, able to stand erect only through the protection of surrounding trees. If very gradually exposed by frequent, light thinnings these may eventually reach dominant positions; but in silviculture it is probably best in most cases to sacrifice these and secure fresh reproduction under greater light. (Pl. VII, fig. 1, and Pl. XIV, fig. 1.)

Within the ranges of red spruce, fir, and hemlock, the culling of these species from the mixed hardwood and softwood stand reduces the seed supply and thereby the proportion of softwoods in the young growth. Although extremely tolerant, hemlock and spruce seedlings are dwarfed, if not killed, by the heavy shade from an unbroken cover of maple and beech crowns, and can succeed only where the shade is lighter, as may be the case under yellow birch crowns. (Pl. VIII.) This is also true of more or less clear cuttings in these woods, for the softwood seedlings are handicapped by their very slow growth in competition with hardwood sprouts and seedlings and with shade-producing underbrush. In spite of this, the softwood reproduction will usually find enough light here and there to persist and in the course of time reappear in the crown cover. In the mountains, the hardwoods and hemlocks are favored by the relatively warm climate and deep, fertile soils of moderate altitude; at higher altitudes the stands are less dense and reproduction less aggressive, so that spruce and fir assume predominance without much difficulty.

Size, rate of growth, and longevity.—The "intensive reproducers" are, as a rule, larger and longer-lived than the "extensive," and the less tolerant of them owe their presence among shade enduring species in virgin stands largely to these two attributes. They must have started before or at the same time as their tolerant neighbors, and kept a dominant position by faster growth and larger size; or have taken advantage of accidents to trees in the stand and sprung up under the increased light thus admitted. Long-lived trees naturally have more chances to establish reproduction under such conditions than short-lived. White pine, white elm, white ash, and basswood owe their presence among heavy-foliaged species largely to these qualities. In the virgin forest they are almost always taller than the surrounding hardwoods, and this affords them plenty of light for seed bearing. The elm is especially favored by its widespreading crown. (Pl. III, fig. 2.) Yellow birch, though of less height, secures crown space and light through the aggressive spread of its slender, flexible twigs and small branches. (Pl. IV, figs. 2 and 3.)

Resistance to various kinds of injury contributes to length of life, and since it varies more or less with climate and soil, it is doubtless at least partly responsible for some regional variations in the composition of the forest. Thus, sugar maple in northern Wisconsin is apt to be inferior to yellow birch in soundness, and is not so abundant. (Pl. II.) Unsoundness does not always influence the forest composition, however. Basswood is extremely unsound, even in the region of its greatest abundance. Its soft wood falls an easy prey to wood-destroying fungi and insects which eat out the hearts of the trees, so that nearly all large basswoods in the old-growth forests are hollow. In spite of this the trees attain great age and size. The reproductive power of large basswoods is apt to be considerably reduced by the breakage of branches in the top, due to snow and wind.

Climate and soil.[1]—Climate has an undoubted selective influence on the composition of these forests, but its precise effect can not easily be disassociated from the other elements determining the composition. In general, however, it appears to restrict the growth of yellow and paper birch and the aspens to the cold, humid air and soil of the north and of fairly high altitudes; the paper birch and aspen extend beyond the Arctic Circle. The wide north and south ranges of most of the hardwoods show that they are less influenced by climate. Some, however, are influenced more than others; for example, in the mountain regions white elm, ash, and basswood are practically confined to warm, lower slopes and sheltered valleys, but beech and sugar maple grow at altitudes as high as those reached by yellow birch. The white elm, ash, and basswood are at their best in the continental climate of the Lake States and southeastern Canada, where they hold their own against the more tolerant beech, maple, and yellow birch. Black birch, though essentially a northern hardwood, is scarce in New England, and its range indicates less hardiness than that of yellow birch. Beech apparently endures greater air dryness than the other northern hardwoods. South of the northern hardwood region it is often a prominent associate of white oak and hickory in relatively dry situations.

As compared with the pines and the hardwoods of the oak-hickory-chestnut types, the northern hardwoods are exacting in their soil requirements. In common with most tree growth they are best suited by deep, fresh, well-drained, fertile loams, mixed with sand or with clay, and kept porous and moist by abundant, well-decomposed humus. It is probable that mycorrhiza and nitrifying soil bacteria

[1] The general climatic conditions within which the northern hardwoods forests grow have been outlined on pp. 3 and 4.

are an important element of fertility in these soils. The northern hardwoods are not confined to rich soils, however. They often thrive on dry or on very shallow soils, but in each case there must be some compensating factor. A shallow soil must be moist, for example, and a dry one deep. In the lower peninsula of Michigan maple, beech, elm, and basswood grow well near the shore of Lake Michigan on deep, dry, fine sand of low agricultural value, while in the eastern part of the State, adjacent to Lake Huron, they are largely replaced on sandy soils by pines or by dry-land hardwoods, principally oaks. The compensating factor here is probably air humidity due to the prevalence of moist winds from Lake Michigan. Under these conditions the growth is more rapid than on heavier, more fertile soil, no farther north, in Wisconsin. Beech is the least exacting species with reference to soil moisture and quality. In Ohio [1] it grows well in limestone soils in mixture with white oak, red oak, hickory, and white ash, and also on well-drained sandy clay moraines with white oak and hickory. It is rather sensitive to changes in the ground-water level through draining, however, as well as by the opening up of the forest crown cover. White elm, basswood, sugar maple, and ash, though apparently less sensitive to such changes, are somewhat more exacting, and in dry climates require a larger amount of soil moisture for their best growth.

The species differ in the ability of their root systems to adapt themselves to soils of different depths and moisture content, but as yet little is known of their capacities in this respect. The soil conditions in which they are found indicate that probably the root systems of sugar maple and yellow birch are the least and those of beech, basswood, and elm the best adapted to draw moisture from a deep but only slightly moist soil. Where the soil and air humidity are ample, the tendency of all the species is in the direction of shallow-rootedness, and vice versa.

FORM.

Tables 50 to 53 (Appendix) show the taper of trees of different species and size, and Tables 5 and 6 give the comparative lengths and breadths of crown of beech, sugar maple, yellow birch, and basswood trees. These figures are average measurements of the crowns of forest trees felled to obtain the growth measurements given in Tables 7 to 9, together with the measurements of the sample trees from the second-growth plots described on pages 21 to 27. No regular variation between crown classes was distinguishable, but practically all the trees measured belonged to the upper crown classes. Both the length and the breadth of the crowns are greatest in the most tolerant and smallest in the least tolerant species, though this

[1] O. E. Baker, in "The forest problem in a rich agricultural county of Ohio," Forestry Quarterly, vol. 1, No. 2, pp. 138–150 (1908).

FIG. 1.—YOUNG TREES IN AN OLD FOREST.

These would probably not survive the removal of the large timber. See Plate XIV, figure 1.

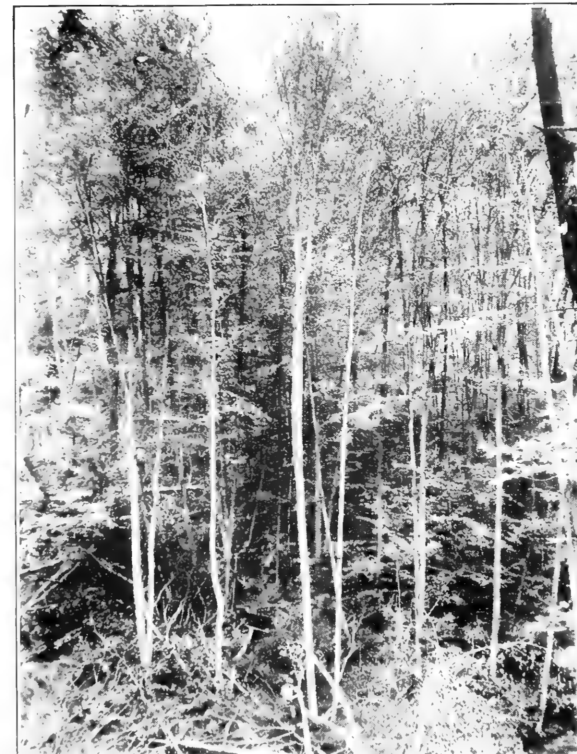


FIG. 2.—A 70-YEAR-OLD STAND, 75 FEET HIGH, WHICH GREW FROM THE START IN THE OPEN.

YELLOW BIRCH IN OLD-GROWTH AND SECOND-GROWTH FORESTS.

RED SPRUCE REPRODUCTION FILLING AN OPENING IN A SECOND-GROWTH STAND OF SUGAR MAPLE AND YELLOW BIRCH NEW HAMPSHIRE.

generalization can not be applied to all species. White elm, for example, may have a wider crown than beech, which is much more tolerant.

TABLE 5.—*Comparative crown widths of northern hardwoods based on diameter breast high.*

Diameter breast high.	Average width of crown.				Diameter. breast high.	Average width of crown.			
	Beech.	Sugar maple.	Yellow birch.	Bass-wood.		Beech.	Sugar maple.	Yellow birch.	Bass-wood.
Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	3	3	3	3	15	31	27	23	20
2	5	5	5	5	16	32	28	25	20
3	8	8	7	8	17	33	29	26	20
4	10	10	9	10	18	34	30	27	21
5	13	13	11	12	19	34	31	28	21
6	15	14	12	14	20	35	32	29	22
7	18	16	14	15	21	36	34	30	22
8	20	18	15	16	22	36	35	31	23
9	22	19	16	17	23	37	36	33	24
10	24	21	18	18	24	37	37	34	24
11	26	22	19	18	25	38	38	35	25
12	28	23	20	19	26	39	39	36	26
13	29	25	21	19					
14	30	26	22	19	Basis, trees	82	67	42	195

TABLE 6.—*Comparative crown lengths of northern hardwoods based on total height of tree.*

Total height of tree.	Average length of crown.				Total height of tree.	Average length of crown.			
	Beech.	Sugar maple.	Yellow birch.	Bass-wood.		Beech.	Sugar maple.	Yellow birch.	Bass-wood.
Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
5	3	2	2	3	70	42	33	31	27
10	6	5	4	5	75	45	36	34	28
15	8	7	6	7	80	48	38	37	29
20	11	9	8	10	85	51	40	40	31
25	14	12	10	12	90	54	43	43	32
30	17	14	12	14	95	56	45	....	33
35	20	16	14	16	100	59	47	....	34
40	23	19	17	18	105	62	50	....	35
45	26	21	19	19	110	65	52	....	36
50	29	24	21	21	115	....	54	....	37
55	32	26	24	23	120	....	57	....	39
60	35	28	26	24					
65	39	31	29	25	Basis, trees	87	72	47	253

GROWTH.

The rate of growth of a given species depends on the soil, the climate, and especially sunlight. Theoretically the growth per acre is the same whether there are few or many trees, provided the supply of light is completely utilized by a continuous crown cover. The northern hardwood forest in its virgin condition was characterized by extreme crown density, caused not only by the large number of trees which the fertile soil produced, but also by the difference in shade endurance. Under the light-needing crowns of the tall pines, elms, or basswoods, the tolerant birch, beech, and maple grew without much difficulty, providing an efficient, wood-producing "lower story" of foliage. The total amount of wood produced was very large.

But, on the other hand, the individual trees grew with extreme slowness, especially the more tolerant. Many of the trees which ultimately became dominant did so only after a long struggle upward toward the light, during which their growth was suppressed by shade almost to the point of extinction. Evidence of this struggle is found when old-growth forest trees are cut, in the great and irregular variation in the width of the annual rings. These irregularities are not, it is true, wholly due to variations in the light supply; climatic fluctuations and the drain caused by heavy seed crops undoubtedly have their effect. But the aggregations of fine rings represent chiefly the periods of suppression by shade, while the wider rings represent the more rapid growth under increased light. In dominant trees, therefore, the rings are apt to be narrower near the heart than elsewhere, and in trees which have long been suppressed they may all be very narrow.

Most of the "intensive" trees of the northern forest retain to a great age their power of recovery from moderate suppression, and this is as true of the less as of the more tolerant. In consequence, a graphic curve based on the growth of an individual virgin forest tree is exceedingly irregular, and bears little resemblance to that of an open-grown tree, in which the growth is at first slow, rapidly reaches a maximum, and then gradually decreases. An average curve representing the growth of many forest trees is commonly almost a straight line.

It is worthy of notice that the fine rings next the bark of large, old trees may be due not to insufficient light, but to the great circumference about which the season's layer of wood must be spread. At the top of the tree, where the circumference is smaller, the growth of the same year will show a much wider ring on cross section.

Tables 7, 8, and 9 show the growth of most of the important "intensive" trees of the northern hardwood forest in the Lake States. They are based on decade measurements of selected, well-formed, sound trees, and represent a growth slightly greater than the average rate.[1] The small number of white elm trees measured (14) was insufficient for thoroughly representative tables; but since the trees were dominant the figures given show fairly well what may be expected of vigorous white elm in unmanaged forests. The principal inference from the table is that the growth rate is more or less in proportion to the tolerance of the species, and that basswood is considerably more rapid growing than any of the others.

[1] The maximum and minimum figures do not indicate extremes, but only averages of maxima and minima. All the measurements were separated into three equal parts, representing maxima, averages, and minima, and each part was averaged (graphically) by a curve. The absolute maxima or minima can be found by halving the difference between the figures given in the "maximum" or "minimum" columns and those given in the "average" column for any desired year, and then increasing the average maximum or decreasing the average minimum by this amount.

TABLE 7.—*Growth in diameter, breasthigh, of northern hardwoods and hemlock in the Lake States.*[1]

Age.	Average growth.						Maximum growth.						Minimum growth.					
	Sugar maple.	Beech.	Yellow birch.	Hemlock.	White elm.	Basswood.	Sugar maple.	Beech.	Yellow birch.	Hemlock.	White elm.	Basswood.	Sugar maple.	Beech.	Yellow birch.	Hemlock.	White elm.	Basswood.
Years.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
20	0.5	0.7	1.1	0.7	0.9	2.2	1.2	1.3	2.1	2.0	2.8	3.3	.....	0.3	.....	0.3	0.1	1.3
30	1.2	1.5	1.7	1.3	1.7	3.6	2.3	2.3	3.3	3.9	4.3	5.1	.....	.7	0.2	.6	.4	2.2
40	1.9	2.3	2.3	2.1	2.5	5.0	3.6	3.3	4.6	5.7	5.7	6.9	0.2	1.1	.4	.9	.7	3.1
50	2.7	3.0	3.0	2.9	3.3	6.5	4.9	4.4	5.8	7.6	7.0	8.8	.5	1.6	.7	1.3	1.0	4.1
60	3.5	3.8	3.8	3.8	4.1	7.9	6.3	5.4	7.1	9.4	8.2	10.7	.8	2.2	1.1	1.6	1.3	5.2
70	4.3	4.6	4.6	4.7	4.9	9.4	7.6	6.5	8.4	11.1	9.3	12.5	1.1	2.8	1.5	2.0	1.6	6.3
80	5.2	5.4	5.6	5.7	5.7	10.9	9.1	7.5	9.8	12.8	10.4	14.3	1.5	3.4	2.1	2.4	1.9	7.4
90	6.1	6.3	6.6	6.7	6.5	12.4	10.5	8.6	11.2	14.5	11.5	16.0	1.9	4.0	2.7	2.7	2.3	8.5
100	7.0	7.1	7.7	7.8	7.3	13.8	11.9	9.6	12.5	16.1	12.6	17.6	2.4	4.7	3.4	3.1	2.7	9.5
110	8.0	8.1	8.9	9.0	8.1	15.1	13.2	10.6	13.9	17.7	13.8	19.0	2.9	5.4	4.2	3.4	3.2	10.7
120	9.0	8.9	10.1	10.0	8.9	16.3	14.5	11.6	15.2	19.4	14.9	20.3	3.5	6.1	5.0	3.8	3.7	11.7
130	10.0	9.8	11.2	11.2	9.7	17.5	15.8	12.6	16.5	21.0	16.0	21.6	4.1	6.9	5.8	4.3	4.2	12.8
140	10.9	10.7	12.3	12.3	10.5	18.5	17.0	13.6	17.8	22.6	17.0	22.9	4.7	7.6	6.7	4.8	4.8	13.8
150	11.9	11.5	13.4	13.4	11.4	19.5	18.2	14.6	19.1	24.2	18.1	24.1	5.4	8.3	7.6	5.3	5.4	14.7
160	12.9	12.4	14.5	14.5	12.2	20.6	19.4	15.5	20.3	25.7	19.2	25.3	6.1	9.1	8.5	5.9	6.0	15.7
170	13.9	13.2	15.6	15.5	13.2	21.5	20.5	16.4	21.6	27.2	20.2	26.4	6.8	9.9	9.5	6.6	6.7	16.6
180	14.8	14.1	16.7	16.5	14.1	22.6	21.5	17.3	22.9	.....	21.3	27.5	7.5	10.6	10.5	7.3	7.5	17.5
190	15.7	14.9	17.8	17.5	15.1	23.6	22.6	18.2	21.1	.....	22.3	28.6	8.3	11.3	11.4	8.0	8.2	18.4
200	16.7	15.7	18.8	18.4	16.0	24.6	23.6	19.1	25.2	.....	23.4	29.7	9.0	12.1	12.2	8.7	9.0	19.3
210	17.6	16.5	19.8	.....	17.0	25.5	24.7	20.0	26.3	.....	24.4	30.7	29.7	12.9	13.1	.....	9.8	20.1
220	18.5	17.3	20.8	.....	17.9	26.5	25.7	20.9	27.5	.....	25.5	31.7	10.5	13.8	13.9	.....	10.7	21.1
230	19.3	18.1	21.8	.....	18.9	27.5	26.7	21.8	28.6	.....	26.5	32.7	11.3	14.6	14.8	.....	11.6	22.0
240	20.3	19.0	22.7	.....	19.9	28.4	27.5	22.7	29.7	.....	27.5	33.8	12.1	15.4	15.5	.....	12.5	22.9
250	21.1	19.9	23.7	.....	20.9	29.4	28.4	23.6	30.8	.....	28.5	34.8	13.0	16.2	16.3	.....	13.5	23.8

[1] Based on the following data: Sugar maple, 80 trees, Charlevoix and Kalkaska Counties, Mich., Price and Iron Counties, Wis.; beech, 74 trees, Charlevoix and Kalkaska Counties, Mich.; yellow birch, 27 trees, Charlevoix and Kalkaska Counties, Mich., Price and Iron Counties, Wis.; hemlock, 186 trees Leelanaw County, Mich.; white elm, 14 trees, Charlevoix and Kalkaska Counties, Mich., Price and Iron Counties, Wis.; basswood, 75 trees, Charlevoix and Kalkaska Counties, Mich., Price and Iron Counties, Wis.

TABLE 8.—*Growth in height of northern hardwoods and hemlock in the Lake States.*[1]

Age.	Average growth (total height).						Maximum growth (total height).					Minimum growth (total height).				
	Sugar maple.	Beech.	Yellow birch.	Hemlock.	White elm.	Basswood.	Sugar maple.	Beech.	Yellow birch.	Hemlock.	Basswood.	Sugar maple.	Beech.	Yellow birch.	Hemlock.	Basswood.
Years.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*
20	10	13	20	8	21	23	18	19	30	18	32	.....	8	.....	6	16
30	18	21	26	12	28	34	29	28	39	31	44	.....	13	8	7	23
40	25	28	31	16	34	43	39	35	48	42	54	7	17	11	8	30
50	32	33	37	20	40	52	48	42	54	53	63	10	22	15	10	37
60	38	39	43	25	45	59	55	48	60	62	70	14	27	20	11	45
70	44	44	48	30	49	66	61	54	64	70	75	17	32	24	13	51
80	49	48	53	35	53	71	67	59	68	76	80	21	36	30	14	57
90	54	53	58	40	57	75	71	64	71	82	83	25	40	35	15	62
100	58	57	62	44	61	78	75	68	73	85	85	29	44	40	17	66
110	62	62	66	49	64	81	78	72	75	88	87	34	48	45	18	70
120	66	65	69	53	67	83	81	75	77	91	89	38	52	50	20	73
130	70	69	71	57	71	85	83	78	79	94	90	43	56	54	21	76
140	72	72	73	60	73	87	85	81	80	96	92	46	59	58	23	78
150	75	75	75	63	76	88	87	83	81	98	93	50	63	61	25	80
160	77	78	76	66	78	89	89	84	82	100	94	54	66	64	27	82
170	80	80	78	68	81	90	90	85	83	102	95	57	69	67	29	84
180	81	82	79	70	83	91	92	86	83	.....	96	61	72	70	31	85
190	83	83	80	72	85	92	93	87	84	.....	97	64	74	71	33	87
200	85	84	81	74	87	93	94	87	85	.....	97	66	77	73	35	88
210	86	85	81	.....	90	94	96	88	86	.....	98	69	79	74	.....	89
220	87	86	82	.....	92	95	97	89	86	.....	98	71	81	75	.....	90
230	89	87	83	.....	93	96	98	90	87	.....	99	73	83	77	.....	91
240	90	87	83	.....	95	96	99	90	87	.....	100	75	84	77	.....	92
250	91	88	84	.....	97	97	100	91	88	.....	100	78	85	78	.....	93

[1] Based on same data as Table 7. The measurements for white elm were too few to warrant maximum and minimum curves.

TABLE 9.—*Growth in volume (cubic) of northern hardwoods and hemlock in the Lake States.*[1]

Age.	Average growth.					Maximum growth.					Minimum growth.				
	Sugar maple.	Beech.	Yellow birch.	Hemlock.	Basswood.	Sugar maple.	Beech.	Yellow birch.	Hemlock.	Basswood.	Sugar maple.	Beech.	Yellow birch.	Hemlock.	Basswood.
Years.	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*
20															
30										2.1					
40					1.5			2.4	2.2	6.4					
50					4.8	2.5	1.8	5.0	6.6	13.0					0.8
60		1.0	1.0		9.2	5.6	3.6	8.1	12.4	22.0					2.2
70	1.5	2.2	2.4		15.5	9.5	5.9	12.1	20.0	33.0					4.5
80	3.0	3.7	4.3	1.8	23.0	14.7	8.7	17.2	29.0	46.0					7.5
90	5.0	5.5	6.8	3.6	32.0	21.0	12.1	24.0	39.0	59.0		1.1			11.4
100	7.3	7.8	10.0	5.9	41.0	29.0	16.5	31.0	50.0	73.0		2.4			16.3
110	10.3	10.5	13.8	9.2	51.0	37.0	21.0	40.0	64.0	87.0		3.8	1.5		22.0
120	14.0	13.8	18.3	12.5	61.0	47.0	27.0	49.0	78.0	101.0		5.3	3.0		28.0
130	18.3	17.6	24.0	17.1	72.0	58.0	34.0	60.0	94.0	115.0	1.1	7.0	4.8		35.0
140	23.0	22.0	30.0	22.0	82.0	69.0	40.0	71.0	112.0	130.0	2.3	9.0	6.8		42.0
150	29.0	27.0	37.0	28.0	93.0	81.0	47.0	82.0	131.0	145.0	3.6	11.5	9.3	1.0	49.0
160	35.0	32.0	44.0	34.0	104.0	93.0	55.0	93.0	152.0	161.0	5.1	14.3	12.3	1.8	57.0
170	42.0	38.0	53.0	40.0	115.0	107.0	62.0	106.0	174.0	177.0	7.0	18.6	16.0	2.6	65.0
180	49.0	44.0	61.0	47.0	126.0	121.0	71.0	119.0		193.0	9.0	21.0	20.0	3.4	73.0
190	57.0	50.0	70.0	54.0	138.0	136.0	79.0	133.0		210.0	11.3	25.0	25.0	4.6	81.0
200	66.0	56.0	79.0	61.0	151.0	151.0	89.0	147.0		228.0	14.1	30.0	30.0	5.9	90.0
210	75.0	63.0	88.0		165.0	168.0	98.0	161.0		247.0	17.3	36.0	35.0		99.0
220	84.0	71.0	98.0		178.0	184.0	109.0	176.0		267.0	21.0	42.0	40.0		109.0
230	94.0	79.0	108.0		192.0	201.0	120.0	191.0		288.0	25.0	48.0	46.0		119.0
240	104.0	87.0	118.0		207.0	218.0	132.0	205.0		311.0	30.0	54.0	52.0		130.0
250	115.0	95.0	128.0		221.0	235.0	143.0	220.0		335.0	35.0	61.0	58.0		141.0

[1] Based on same data as Table 7.

SECOND GROWTH.

Before lumbering began young growth of the intensive species was practically confined to individuals and groups of various ages within the virgin forest. Fires, windfall, and other accidents to the stand undoubtedly resulted in some even-aged reproduction over small areas, but only a small amount as compared with the reproduction of the extensive species. In 1825, for example, fires denuded an area in New Brunswick and northern Maine estimated at more than 5,000,000 acres, over the greater part of which aspen and paper-birch thickets sprang up. In the shade of these the more intensive species came in irregularly, producing relatively uneven-aged stands.

As a result of widespread logging operations and the fires which have followed them, even-aged second-growth stands of the intensive species have become fairly numerous, especially in the rough eastern part of the northern hardwood region, where more of the land has been allowed to revert to forest. It is common for these stands to be of mixed species, one or two of which predominate over the others in number and size. Over small areas a single species may grow in almost pure stands. Yellow birch is the most frequent example

FIG. 1.—A CLUMP OF MERCHANTABLE BASSWOOD SPROUTS FROM A SINGLE STUMP. TENNESSEE.

FIG. 2.—THREE MONTHS AFTER A FIRE, CLUMPS OF BASSWOOD SPROUTS WERE PRACTICALLY THE ONLY LIVING VEGETATION. NORTHERN WISCONSIN.

BASSWOOD, NEXT TO CHESTNUT, IS THE BEST SPROUTER.

FIG. 1.—AN 80-YEAR-OLD STAND OF YELLOW BIRCH IN PENNSYLVANIA.

Illustrates plot No. 9, p. 24.

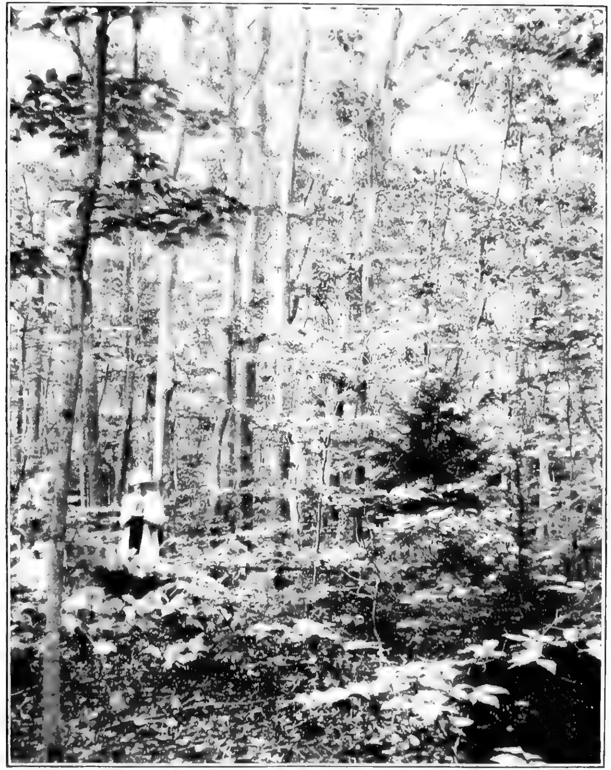


FIG. 2.—A 95-YEAR-OLD BEECH STAND IN NEW HAMPSHIRE.

Illustrates plot No. 13, p. 25.

EVEN-AGED SECOND-GROWTH HARDWOOD STANDS. "OLDER THAN THEY LOOK."

within its geographical range. Substantially pure, even-aged yellow birch stands are especially abundant in the eastern mountains from Maine to Pennsylvania. (Pl. X, fig. 1.) Pure, even-aged stands of sugar maple or of beech are uncommon (Pl. X, fig. 2), and basswood and elm hardly ever predominate in the second-growth except in small groups among other species.

The following measurements of second-growth hardwood stands made in the course of the study illustrate the growth and composition of young forests of various ages and species. The measurements were made in small sample plots, the sizes of which are given; and the volumes and ages were determined by means of sample trees representing arbitrarily fixed diameter groups.[1] The volumes are on an acre basis. As a matter of fact, the composition represented by a sample plot was in most cases less than an acre in extent, the plot representing that portion of the second-growth stand in which the desired species was most abundant. The stands were selected at random and show about the average growth, in cubic feet and cords, for the mountain lands.[2] The volume measurements were of merchantable fuel wood material in trees 3 inches and over in breast-high diameter to a minimum diameter limit of about 2 inches. The cubic-foot volumes were reduced to cords by dividing by 85. The crown density is shown in tenths, perfect density being 1. The crown density of birch stands, however, is rarely greater than 0.9, which may be considered perfect.

BIRCH PLOTS.

NEW HAMPSHIRE.

Plot No. 1.—Age, 43 years; yield, 24.2 cords per acre; height of dominant trees, 55 to 60 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Yellow birch	88.0	496	5.8	2 to 10	1,806	45.15
Paper birch	8.0	40	6.1	3 to 10	166	4.15
Sugar maple	2.2	24	4.2	2 to 5	46	1.15
Fire cherry (dead)	1.8	16	4.5	3 to 5	38	.95
Total	100.0	576			2,056	51.40

Benton township, Grafton County, N. H., near Glencliff; western slope of Mount Moosilauke; altitude 1,500 feet; slope 25 per cent west by north; soil rather shallow, loamy sand with 3 inches of humus; plot one-eighth acre, representing one-fourth acre stand surrounded by uneven-aged growth; density 0.8; reproduction, sugar and red maple, abundant.

[1] This method is described in H. S. Graves's "Forest mensuration," pp. 229–231, 1906.

[2] The yield of mixed second-growth hardwood stands in Vermont is given in Vermont Agricultural Experiment Station Bulletin 176, "The management of second-growth hardwoods in Vermont."

Plot No. 2.—Age, 75 to 80 years; yield, 22.9 cords per acre; height of dominant trees, 50 to 55 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Yellow birch	78.2	360	6.1	2 to 12	1,519	19.00
Beech	14.7	328	3.5	1 to 7	286	3.58
Sugar maple	7.1	456	2.2	1 to 6	138	1.73
Total	100.0	1,144			1,943	24.31

Milan Township, Coos County, N. H., 3 miles east of west Milan; altitude 1,300 feet; slope 5 per cent north; soil fine, fresh, brown loam, very stony, medium depth, humus 2 inches deep; plot one-eighth acre in strip of second-growth 2 chains wide at south end of an old hardwood stand; density 0.9; reproduction, beech and sugar maple seedlings quite abundant, no birch; numerous maple seedlings killed by shade.

Plot No. 3.—Age, 88 years; yield, 38.6 cords per acre; height of dominant trees, 60 to 65 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Yellow birch	63.9	368	6.8	2 to 14	2,097	23.83
Paper birch	30.6	128	7.6	2 to 13	1,005	11.42
Beech	4.5	52	4.9	1 to 10	147	1.67
Sugar maple	.6	4	6.5	2 to 9	21	.24
Aspen	.4	2	7.0		13	.15
Red spruce		416	2.2	1 to 6		
Balsam fir		36	2.2	1 to 3		
Total	100.0	1,006			3,283	37.31

Benton Township, Grafton County, N. H., near Glencliff; west slope of Mount Moosilauke; altitude 2,000 feet; slope 17 per cent; exposure northwest; soil fairly deep sandy loam with 3 to 4 inches of humus; plot one-half acre, in stand running largely to paper birch; density 0.9; reproduction, red spruce, heavy, of very slow growth.

NEW YORK.

Plot No. 4.—Age, 20 years; yield, 10.8 cords per acre; height of dominant trees, 35 to 40 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Yellow birch	56.2	2,288	2.1	1 to 4	518	25.90
Black birch	15.0	336	2.4	1 to 4	138	6.90
Sugar maple	14.2	288	2.4	1 to 4	131	6.55
Fire cherry	11.1	80	3.4	3 to 4	102	5.10
Red maple	3.5	48	2.7	2 to 3	32	1.60
Beech		320	1.0			
Service berry		32	1.6	1 to 2		
Total	100.0	3,392			921	46.05

Colchester Township, Delaware County, N. Y.; altitude 1,300 feet; slope 10 per cent northwest; soil very scant; fresh, loamy sand with thin humus layer, over large, flat, loose sandstone fragments; plot one-eighth acre, in stand of 2 or 3 acres, varying in composition; density 0.9; reproduction absent.

Plot No. 5.—Age, 42 years; yield, 25.8 cords per acre; height of dominant trees, 55 to 60 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Yellow birch	54.1	360	5.2	2 to 8	1,185	28.21
Red maple	26.9	160	5.4	3 to 9	588	14.00
Black birch	17.8	104	5.6	4 to 7	390	9.29
Beech	1.2	96	2.4	1 to 4	26	.62
Sugar maple		16	2.0			
Total	100.0	736			2,189	52.12

Colchester Township, Delaware County, N. Y.; altitude 1,300 feet; slope 5 per cent west; soil very scant fresh, brown, loamy sand with thin humus layer, over large, flat, loose sandstone fragments: plot one eighth acre, in 2 or 3 acre stand of second growth with scattered old trees; density, 0.7 to 0.8; reproduction beech and sugar maple, numerous.

PENNSYLVANIA.

Plot No. 6.—Age, 25 years; yield, 11.5 cords per acre; average height of dominant trees, 40 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Fire cherry	48.3	312	3.9	2 to 6	470	18.80
Yellow birch	42.7	1,368	2.4	1 to 6	416	16.64
Black birch	8.4	440	1.9	1 to 4	82	3.28
Striped maple	.6	56	1.9	1 to 3	6	.24
Beech		184	1.2	1 to 2		
Sugar maple		80	1.2	1 to 2		
Total	100.0	2,440			974	38.96

Near Austin, Potter County, Pa.; altitude 1,600 feet; slope 15 per cent north; soil shallow, fresh, clay loam, over small, flat, shale fragments; humus 3 inches deep; plot one-eighth acre, in similar stand of 60 to 80 acres, following lumbering and fire on hemlock land; density 0.9; reproduction absent; many dead fire cherries still standing indicate rapid elimination of this species. Stand apparently thinning itself rapidly; birch largely sprouts.

Plot No. 7.—Age, 40 years; yield, 21.1 cords per acre; average height of dominant trees, 55 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Yellow birch	49.1	420	4.3	2 to 8	881	22.02
Black birch	37.0	332	4.2	2 to 7	664	16.60
Red maple	8.1	100	3.9	1 to 7	146	3.65
Sugar maple	2.4	96	2.4	1 to 6	44	1.10
Black cherry	1.3	8	5.0	5	23	.58
Service berry	1.2	16	3.6	2 to 6	21	.53
Ironwood	.9	56	2.2	1 to 5	16	.40
Beech		156	1.0	1 to 2		
Blue beech		4	1.0	1		
Hemlock		8	1.0	1		
Total	100.0	1,196			1,795	44.88

Near Costello, Potter County, Pa.; altitude 1,600 feet; slope 25 per cent northwest; soil scant, gray loam, dry and crumbly, in interstices of small, fine grained standstone fragments; humus 3 inches thick; density 0.9; reproduction, beech and sugar maple, numerous; a few hemlock seedlings.

Plot No. 8.—Age, 50 years; yield, 10.9 cords per acre; average height of dominant trees, 45 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Yellow birch	76.4	672	3.4	2 to 5	709	14.18
Black birch	21.5	272	2.8	2 to 5	200	4.00
Service berry	1.3	8	4.0	4	12	.24
Cucumber	.8	8	3.0	3	7	.14
Total	100.0	960			928	18.56

Endeavor, Forest County, Pa.; altitude 1,200 feet; slope 5 per cent north; soil, shallow, rich, residual clay loam, over flat shale fragments; humus heavy, rich, well decomposed; plot one-eighth acre, in second-growth stand of less than one-fourth acre; density 0.85; reproduction scant; scattered hemlock, white ash, sugar and red maple, white oak and birch.

Plot No. 9.—Age, 80 years; yield, 42.2 cords per acre; average height of dominant trees, 75 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Yellow birch	85.4	324	7.4	5 to 11	3,062	38.28
Black birch	8.2	32	7.3	5 to 10	296	3.70
Hemlock	4.6	68	5.7	1 to 9	164	2.05
Beech	.8	84	3.0	1 to 6	29	.36
Sugar maple	.6	24	3.1	1 to 6	20	.25
Red maple	.4	20	3	3	16	.20
Total	100.0	552			3,587	44.84

Homer Township, Potter County, Pa.; altitude 1,600 feet; slope 30 per cent west; soil very scant, rich, fresh, residual clay, over talus of flat shale fragments; humus heavy, moist, well decomposed; plot one-fourth acre, in similar stand of more than 10 acres; density 0.9; reproduction scant; beech, red maple, hemlock. (See Pl. X, fig. 1.)

MAPLE PLOTS.

New York.

Plot No. 10.—Age, 39 years; yield, 28 cords per acre; average height of dominant trees, 68 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Sugar maple	77.9	712	4.4	1 to 9	1,852	47.49
Yellow birch	8.3	56	5.1	4 to 6	198	5.08
Fire cherry	7.6	32	6.3	5 to 8	181	4.64
Service berry	2.8	16	5.5	5 to 6	66	1.69
Ironwood	1.8	32	3.3	3 to 4	42	1.08
Basswood	1.6	8	6.0	6	39	1.00
Total	100.0	856			2,378	60.98

Cooks Falls, Delaware County, N. Y.; altitude 1,300 feet; slope 15 per cent east by north; soil moist, sandy loam, relatively deep; humus 1 inch thick; plot one-eighth acre in similar stand of 2 or 3 acres; density 1; reproduction, sugar maple and beech; maple very abundant but badly suppressed; an "old field" stand of seedling origin.

MICHIGAN.

Plot No. 11.—Age, 42 years; yield, 16.2 cords per acre; height of dominant trees, 45 to 50 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high. Average.	Diameter breast-high. Extremes.	Volume per acre.	Average annual growth per acre.
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Sugar maple	53.2	2,224	2.2	1 to 6	731	17.40
White ash	19.5	128	4.5	2 to 7	267	6.36
Ironwood	19.3	72	5.8	2 to 8	265	6.31
Beech	5.4	40	4.2	1 to 7	74	1.76
Service berry	2.6	32	3.5	2 to 5	36	.86
Total	100.0	2,496			1,373	32.69

Glen Haven, Leelanau County, Mich., one-half mile from Lake Michigan; altitude 600 feet; slope level; soil fine, wind transported, lake sand, blackish near surface; humus thin; produces fair corn crops, but difficult to get a "grass catch," due to wind; plot one-eighth acre, in similar stand of several hundred acres; density 0.8. This stand contained from 5 to 20 red oak trees per acre, conspicuously larger than the surrounding trees, and often 10 or 12 inches in diameter. The situation is much better adapted for red oak or white pine than for northern hardwoods.

BEECH PLOTS.

NEW HAMPSHIRE.

Plot No. 12.—Age, 70 years; yield, 22.9 cords per acre; average height of dominant trees, 55 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high. Average.	Diameter breast-high. Extremes.	Volume per acre.	Average annual growth per acre.
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Beech	58.0	952	3.4	1 to 8	1,129	16.13
Sugar maple	33.1	208	5.1	2 to 9	644	9.20
Paper birch	8.9	32	6.4	4 to 8	174	2.49
Yellow birch		16	2.0	2		
Striped maple		8	2.0	2		
Total	100.0	1,216			1,947	27.82

Shelburne Township, Coos County, N. H.; altitude 1,400 feet; slope 20 per cent east; soil rather shallow, fresh, sandy loam, from decomposition of granite; humus 3 inches deep, well decomposed; plot one-eighth acre, a fair sample of at least 5 acres, containing some red oak; density 0.85 to 0.9; reproduction almost exclusively beech seedlings and root sprouts, slender and suppressed; about 10 spruce seedlings per acre. This stand evidently sprang up after a fire in a stand containing beech and hemlock, of which a few decayed stubs are still standing.

Plot No. 13.—Age, 95 years; yield, 33.1 cords per acre; average height of dominant trees, 55 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high. Average.	Diameter breast-high. Extremes.	Volume per acre.	Average annual growth per acre.
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Beech	91.5	524	4.4	1 to 9	2,571	27.06
Red maple	4.6	24	4.7	1 to 6	130	1.37
Paper birch	3.9	4	10.0	10	109	1.15
Hemlock		12	1.0	1		
Total	100.0	564			2,810	29.58

Near Intervale, N. H.; altitude 1,000 feet; slope 8 per cent, north; soil fresh, sandy loam, gravelly and rocky, with $1\frac{1}{2}$ inches of well-decomposed humus; plot one-eighth acre, in stand of 10 or 15 acres, containing a few larger red oak and red maple; density 1.0; reproduction principally striped maple and beech, with clumps of hemlock; some sugar and red maple and scattered small white pine seedlings. This is an unusually pure stand of beech on soil better fitted for raising red oak, white pine, and other rapid growing species. (See Pl. X, fig. 2.)

MIXED PLOTS.

NEW YORK.

Plot No. 14.—Age, 18 years; yield, 7.8 cords per acre; average height of dominant trees, 34 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high. Average.	Diameter breast-high. Extremes.	Volume per acre.	Average annual growth per acre.
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Yellow birch	27.4	496	2.5	1 to 4	182	10.11
Basswood	25.3	360	2.8	1 to 5	168	9.33
Sugar maple	19.7	936	2.1	1 to 5	131	7.28
White ash	10.7	80	3.4	1 to 7	71	3.94
Fire cherry	9.9	64	3.8	1 to 6	66	3.67
Ironwood	3.3	152	2.1	1 to 4	22	1.22
Beech	2.6	144	1.6	1 to 5	17	.94
Aspen	1.1	8	3.0	3	7	.39
Striped maple	....	32	1.8	1 to 2	....	....
Total	100.0	2,272	....	....	664	36.88

Cooks Falls, Delaware County, N. Y.; altitude 1,300 feet; slope 20 per cent, east by south; soil very shallow, fine, crumbly loam, fresh and rich, very full of flat sandstone fragments; humus 2 inches deep, well decomposed; plot one-eighth acre in similar stand of 8 or 10 acres, which contains scattered older trees. The trees are mostly of sprout origin. Basswood and ash, especially, grew in clumps of numerous sprouts, from small stump. Density 0.9; reproduction, a few unthrifty sugar-maple seedlings.

Plot No. 15.—Age, 32 years; yield, 19.8 cords per acre; average height of dominant trees, 48 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high. Average.	Diameter breast-high. Extremes.	Volume per acre.	Average annual growth per acre.
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Red maple	27.4	632	3.4	1 to 6	692	21.62
Black cherry	25.3	176	4.7	2 to 7	391	12.22
Aspen	19.7	120	4.7	3 to 7	318	9.94
White ash	10.7	80	3.7	1 to 6	104	3.25
Beech	9.9	1,624	1.5	1 to 4	84	2.62
Yellow birch	3.3	32	3.6	1 to 5	41	1.28
Service berry	2.6	56	2.8	1 to 4	41	1.28
Sugar maple	1.1	216	1.5	1 to 3	8	.25
Total	100.0	2,936	....	....	1,679	52.46

Cooks Falls, Delaware County, N. Y.; altitude 1,300 feet; slope 10 per cent, south; soil very shallow, fresh, sandy loam, very full of rock fragments; humus rather dry, 1½ inches deep; plot one-eighth acre, representative of more than 10 acres of second growth, containing scattered larger trees; density 1, but south exposure permits golden rod among the ground cover. The beech are mostly root sprouts 1 and 2 inches in diameter, and most of these are badly suppressed, many dying, and some dead. The dead and dying were not counted. Reproduction occasional aspen, red maple, and cherry seedlings; none of beech. This plot is in the same stand as the thinned plot described last in this list.

Plot No. 16.—Age, 42 years; yield, 30.6 cords per acre; average height of dominant trees, 70 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high. Average.	Diameter breast-high. Extremes.	Volume per acre.	Average annual growth per acre.
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Yellow birch	50.8	288	5.8	3 to 10	1,323	31.50
Red maple	30.1	88	7.5	2 to 12	785	18.69
Beech	15.1	136	4.8	1 to 10	394	9.38
Sugar maple	4.0	16	6.5	2 to 9	103	2.45
Total	100.0	528	....	....	2,605	62.02

Colchester Township, Delaware County, N. Y.; altitude 1,300 feet; slope 20 per cent, east by south; soil very scant, fresh, brown, loamy sand with thin humus layer, over large, flat, loose sandstone fragments; plot one-eighth acre, surrounded by mixed second-growth containing scattered older trees; density 0.9; reproduction, a few larger seedlings of yellow birch and red and sugar maples.

Plot No. 17.—Age, 45 years; yield, 24.9 cords per acre; height of dominant trees, 55 to 60 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
Red maple	40.5	228	5.5	1 to 10	856	19.02
Yellow birch	26.9	348	4.0	1 to 9	570	12.67
Black birch	26.4	124	5.9	2 to 9	558	12.40
Sugar maple	4.1	96	3.0	1 to 7	86	1.91
Beech	1.1	116	2.1	1 to 4	24	.53
Fire cherry	.5	8	3.8	1 to 5	11	.24
Service berry	.3	20	2.6	1 to 4	7	.16
Ironwood	.2	8	2.3	1 to 3	4	.09
Total	100.0	948	....	....	2,116	47.02

Colchester Township, Delaware County, N. Y.; altitude 1,400 feet; slope 20 per cent, northwest; soil very scant, fresh, brown, loamy sand in interstices of loose sandstone fragments; humus thin; plot one-fourth acre, in similar stand covering 1 or 2 acres; density 0.9; reproduction very scanty; a few small sugar maple and birch seedlings, and an occasional hemlock sapling; most of the red maples and beeches are sprouts; the birches are mostly seedlings.

THINNED PLOT.

[Originally similar to plot No. 15 in composition and yield.]

Plot No. 18.—Age, 32 years; yield, 9.7 cords per acre; average height of dominant tree, 50 feet.

Species.	Proportion based on volume.	Number of trees per acre.	Diameter breast-high.		Volume per acre.	Average annual growth per acre.
			Average.	Extremes.		
	Per cent.		*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*
White ash	44.7	200	4.2	2 to 6	370	11.56
Red maple	43.8	104	5.8	4 to 8	262	11.31
Black cherry	9.0	16	6.5	6 to 7	74	2.31
Basswood	2.5	8	5.0	5	21	.66
Red maple sprout clumps, 3 years old	....	560	....	....	....	....
Total	100.0	888	....	....	827	25.84

Cooks Falls, Delaware County, N. Y.; altitude 1,300 feet; slope 10 per cent, south; soil very shallow, fresh, sandy loam, full of rock fragments; humus scanty; plot one-eighth acre, representative of 5 or 6 acres similarly thinned. The stand was heavily thinned 3 years before, when from 10 to 15 cords per acre of 4-foot wood were removed. The material removed was chiefly yellow and black birch, sugar maple, red maple, beech, and ironwood. Density 0.7; reproduction, heavy sprout reproduction of red maple, averaging about 8 feet high. Numerous 1-year-old seedlings of black cherry and red maple, and unthrifty breech sprouts. (See Pl. XV, fig. 1.)

ECONOMIC IMPORTANCE.

GENERAL UTILITY.[1]

In the amount and total value of their products the northern hardwoods have always been overshadowed by the softwoods, particularly white pine. They have in the past contributed but little to the purposes which require wood in large quantities, like general construction, box making, and paper making, so that the hardwood-lumber cut of the country has been less than a quarter of the total lumber cut. On the other hand, the average value of hardwood

[1]An account of the characteristics and uses of the wood of beech and various species of maple and birch is given in Department of Agriculture Bulletin No. 12, "Uses of commercial woods of the United States: Beech, birches, and maples," 1913.

lumber in 1912 exceeded that of softwood by 25 per cent. Hardwoods are indispensable for hundreds of uses none the less important because they demand a relatively small supply. Among them are finishing, flooring, furniture, turnery, "novelties," woodenware, handles, shuttles, bobbins, spools, vehicles, veneer boxes and baskets, and many others, none of which use much, but which in the aggregate consume a great and increasing quantity of hardwood material. In certain regions hardwoods now compete actively with softwoods in box making and to some extent in construction. They furnish the greater part of the wood used for fuel in the hardwood region. The manufacture of wood alcohol and charcoal is supported by maple, beech, and birch (Pls. XI and XII), and practically all the northern hardwoods are now used in paper production (Pl. XIII).

ANNUAL CUT.

The annual cut in 1912 of the principal northern hardwoods is shown in Table 8, prepared from the census report for that year.[1] The proportion of these species, individually and collectively, contained in the total hardwood cut in each of the States and in the whole northern hardwood region is also given.

TABLE 8.—*Annual lumber cut (1912) of the principal hardwoods of the northern hardwood forest, with the proportion of each in the total hardwood cut of the States and the United States.*

[Compiled from data in Census Bureau circular, "Forest products: Lumber, lath, and shingles, 1912."]

Species.	Maine.		New Hampshire.		Vermont.		New York.	
	Quantity.	Per cent of all hardwoods cut.	Quantity.	Per cent of all hardwoods cut.	Quantity.	Per cent of all hardwoods cut.	Quantity.	Per cent of all hardwoods cut.
	Mft. b. m.		*Mft. b. m.*		*Mft. b. m.*		*Mft. b. m.*	
Maple	11,423	12.5	11,256	18.3	30,435	31.4	76,891	30.7
Birch	51,110	55.8	18,132	29.4	31,551	32.5	31,395	12.5
Beech	7,264	8.0	8,986	14.6	13,144	13.5	40,761	16.3
Basswood	5,499	6.0	1,493	2.4	7,957	8.2	28,513	11.4
Elm	407	.4	350	.6	1,348	1.4	13,684	5.5
Total	75,703	82.7	40,217	65.3	84,435	87.0	191,244	76.4

Species.	Pennsylvania.		Michigan.		Wisconsin.		Minnesota.	
	Quantity.	Per cent of all hardwoods cut.	Quantity.	Per cent of all hardwoods cut.	Quantity.	Per cent of all hardwoods cut.	Quantity.	Per cent of all hardwoods cut.
	Mft. b. m.		*Mft. b. m.*		*Mft. b. m.*		*Mft. b. m.*	
Maple	81,617	16.0	453,110	60.7	118,765	27.1	1,255	2.2
Birch	17,666	3.5	55,350	7.4	140,071	32.0	6,452	11.4
Beech	49,686	9.7	92,106	12.3	2,913	.7	117	.2
Basswood	10,925	2.1	53,533	7.2	79,389	18.1	13,713	24.3
Elm	2,994	.6	52,757	7.1	50,608	11.6	12,245	21.7
Total	162,888	31.9	706,856	94.7	391,746	89.5	33,782	59.9

[1] Bureau of the Census: Forest products—Lumber, lath, and shingles, 1912.

FIG. 1.—A BRANCH WHICH WILL BE TAKEN FOR DISTILLATION.

Such material was formerly left in the woods to rot.

FIG. 2.—TOPWOOD SKIDDED OUT FOR RAILROAD SHIPMENT TO THE CHEMICAL FACTORY.

UTILIZING CROOKED HARDWOOD TOPS AND BRANCHES FOR CHEMICAL DISTILLATION. MICHIGAN.

FIG. 1.—A WOODS CREW SAWING UP AND SPLITTING LARGE BEECH TREES INTO CHEMICAL WOOD.

FIG. 2.—MORE THAN A CORD OF 4-FOOT WOOD FROM A SINGLE SUGAR-MAPLE TREE.

LOG TIMBER TO BE BURNED FOR CHEMICALS AND CHARCOAL. PENNSYLVANIA.

TABLE 8.—*Annual lumber cut (1912) of the principal hardwoods of the northern hardwood forest, with the proportion of each in the total hardwood cut of the States and the United States*—Continued.

Species.	Total for the northern hardwood region.			Total for the United States.		
	Quantity.	Per cent of all hardwoods cut.	Per cent of total lumber cut in this region.	Quantity.	Per cent cut in northern hardwoods region.	Per cent of total lumber cut (soft and hard).
	Mft. b. m.			*Mft. b. m.*		
Maple	784,752	34.8	10.5	1,020,864	76.9	2.6
Birch	351,727	15.6	4.7	388,272	90.6	1.0
Beech	214,977	9.5	2.9	435,250	49.4	1.1
Basswood	201,022	8.9	2.7	296,717	67.7	.8
Elm	134,393	6.0	1.8	262,141	51.3	.7
Total	1,686,871	74.9	22.5	2,403,244	70.2	6.2

In per cent of the total lumber cut (soft and hard) in each State the combined cut of the five hardwoods was as follows:

Maine	8.6	New York	38.1	Wisconsin	26.1
New Hampshire	8.4	Pennsylvania	16.6	Minnesota	2.4
Vermont	35.8	Michigan	47.5		

The figures given for maple, birch, and elm each cover more than one species, as no distinction of species is made by the census. Commercial maple is principally "hard" (sugar) maple, but includes some "soft" (red and silver) maple. Commercial birch in the Lake States is almost entirely yellow birch, but in New England includes also some "white" (paper) birch, and in New York and Pennsylvania some "cherry" (sweet) birch; heart lumber is known as "red" birch. Elm lumber is made, in the north, from three species—white, slippery or "red," and cork or "rock" elm. Much the greater part is undoubtedly white elm, which is known on the market as "gray" or "soft" elm. Much rock elm has been cut in the past, but the remaining supply is small. Some slippery or "red" elm is cut in the Lake States and the northeast, but it is impossible to tell how much of the total elm cut it forms.

Table 8 does not tell the whole story. An immense amount of northern hardwood is used for house fuel. According to estimates for 1908 secured by the Forest Service (Circular 181), the total fuel wood consumption of the Northeastern and Lake States was 16,400,000 cords, of which probably a third was northern hardwoods. About 1,150,000 cords were consumed in 1909 for wood distillation,[1] and as this industry has been extended from New York and Pennsylvania into the Lake States, the amount now used annually for distillation is undoubtedly much greater. Paper-pulp manufacture consumed 31,390 cords of beech alone in 1909 (loc. cit.).

[1] Forest products of the United States, 1909. Bureau of the Census. Compiled in cooperation with the Forest Service.

The census figures for 1909 show the following amounts of the various hardwoods used for making veneers in the northern hardwood region:

	Board feet.
Maple	29,219,000
Birch	23,064,000
Basswood	12,119,000
Elm	11,951,000
Beech	6,700,000
Total	83,053,000

The consumption for slack cooperage stave manufacture for the same year was as follows:

	Staves.	Equivalent in board feet.
Beech	249,761,000	83,253,667
Elm	138,761,000	46,253,667
Maple	107,969,000	35,989,667
Birch	78,224,000	26,074,667
Basswood	62,720,000	20,906,666
Total	637,435,000	212,478,334

In terms of lumber, the aggregate annual consumption for all purposes of these five hardwoods in the Northeastern and Lake States alone is probably 5,500,000,000 board feet. Including the amount not usable, and therefore left in the woods, or burned as refuse or mill fuel, it undoubtedly exceeds 6,000,000,000 board feet, or 12,000,000 cords.

The depreciation both in extent and quality of the northern forests through lumbering, fire, decay, insects, and other causes has already been mentioned. Concurrent with the decrease in softwood timber there has occurred a relative increase in hardwood exploitation, and a similar increase in the cut of inferior hardwoods. From 1899 to 1912 the recorded annual lumber cut of northern hardwoods increased from less than 10 to more than 22 per cent of the total lumber cut. The increase in the several States is shown in Table 9:

TABLE 9.—*Increase in proportion of northern hardwoods in the aggregate lumber cut of all species, from 1899 to 1912.*

State.	Proportion of northern hardwoods cut to total cut.			State.	Proportion of northern hardwoods cut to total cut.		
	1899	1912	Increase.		1899	1912	Increase.
	Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
Maine	7.3	8.6	1.3	Michigan	19.5	47.5	28.0
New Hampshire	1.1	8.4	7.3	Wisconsin	10.9	26.1	15.2
Vermont	11.2	35.8	24.6	Minnesota	.8	2.4	1.6
New York	15.7	38.1	22.4				
Pennsylvania	4.9	16.4	11.5	Average [1]	9.8	22.5	12.7

[1] Based on actual lumber cut figures; not on the percentages above listed.

The amount of increase serves indirectly as an index to the States in which large supplies of conifers yet remain. Spruce in Maine and white pine in Minnesota still hold first place. The relatively small increase in the northern hardwoods cut in Pennsylvania is due partly to the influence of the large hemlock cut, and partly to that of the southern hardwoods, especially oak.

PRESENT SUPPLY.

There is little hope of finding out the amount of standing northern hardwoods except within a very wide "limit of error." The estimates are given in Table 10, therefore, merely as rough approximations. They are based on estimates of the total forest areas in the different States, the proportions occupied by northern hardwoods, and the probable average stand per acre (from 1,000 to 3,000 board feet). Each of these factors is, of course, subject to wide error, and there is the further error arising from differences in the closeness of utilization and in the prevalence of defect.

TABLE 10.—*Estimated stand of hardwood timber in the northern hardwood forest.*[1]

State.	Stand.	State.	Stand.
	Board feet.		*Board feet.*
Maine	7,000,000,000 to 15,000,000,000	Southern Appalachian States	10,000,000,000 to 15,000,000,000
New Hampshire	4,000,000,000 to 5,000,000,000	Lake States	30,000,000,000 to 30,000,000,000
Vermont	4,000,000,000 to 5,000,000,000		
New York	10,000,000,000 to 20,000,000,000		
Pennsylvania	10,000,000,000 to 20,000,000,000	Total	75,000,000,000 to 110,000,000,000

[1] Acknowledgment is made to State Foresters A. F. Hawes, E. C. Hirst, and C. R. Pettis for assistance received in the preparation of these estimates. For the Lake States estimates compiled by the Bureau of Corporations in 1910 and published in its report on standing timber (1913) were used. These were brought down to date by deducting an equivalent of five years lumber cut.

VALUE OF STANDING TIMBER.

There is normally a wide range in the stumpage value of any species, the price depending not only upon the accessibility and quality of the timber, but also upon the condition of the market, the exigency of the sale, and other matters common to all property exchange. Since, however, the remaining virgin timber in the Northeastern and Lake States is roughly uniform as to accessibility (a result of fairly similar logging and trade conditions) stumpage values for a given species tend to approach a standard market value. Statistics of this nature were obtained by the Forest Service through a canvass of timberland owners in 1907, and again in 1912. The averaged results, with reference only to the principal species of the northern hardwood forest, are given in Tables 11 and 12.

TABLE 11.—*Comparative stumpage values per 1,000 board feet of the more important species of the northern hardwood region: 1912.*

[From reports of sales collected by the Forest Service, Office of Industrial Investigations.]

Species.	Northeastern States.[1]	Lake States.[2]	Southern States.[3]	Species.	Northeastern States.[1]	Lake States.[2]	Southern States.[3]
Maple	$5.98	$4.58	$3.45	Elm	$8.40	$5.87	$3.41
Birch	5.61	4.85	3.33	Ash	9.03	5.82	6.16
Beech	4.38	3.67	2.86	White pine	8.44	10.39	3.91
Basswood	8.40	6.30	4.92	Hemlock	6.28	3.78	2.62

[1] Maine, New Hampshire, Vermont, Massachusetts, New York, and Pennsylvania.
[2] Minnesota, Wisconsin, and Michigan.
[3] Maryland, Virginia, West Virginia, Kentucky, Tennessee, and North Carolina.

While the figures in Table 11 are based on many reports of actual sales of stumpage, they are of practical value only in showing the general tendency of prices in these regions.

TABLE 12.—*Average stumpage values of northern hardwoods for 1907 and 1912.*

Species and year.	Northeastern States.						North Central States.		
	Average of five States.	Maine.	New Hampshire.	Vermont.	New York.	Pennsylvania.	Average of two States.	Ohio.	Indiana.
Maple:									
1907	$4.37[174]	$4.30[25]	$4.46[25]	$3.22[32]	$4.84[28]	$4.74[64]	$7.55[89]	$7.19[35]	$7.79[54]
1912	**5.34**[309]	**4.84**[56]	**5.21**[33]	**4.28**[29]	**6.00**[91]	**5.37**[100]	**7.68**[169]	**7.42**[86]	**7.94**[83]
Birch:									
1907	4.90[161]	4.78[30]	4.50[26]	3.52[31]	5.63[24]	5.70[50]	6.50[4]	....	6.50[4]
1912	**5.44**[261]	**4.89**[65]	**5.67**[38]	**4.81**[27]	**6.14**[69]	**5.38**[62]	**4.05**[11]	**4.70**[5]	**3.50**[6]
Beech:									
1907	3.67[147]	4.38[21]	3.39[22]	2.72[25]	3.02[25]	4.25[54]	5.80[94]	5.36[38]	6.10[56]
1912	**4.28**[263]	**4.31**[52]	**4.31**[31]	**3.50**[29]	**4.55**[77]	**4.28**[74]	**6.10**[163]	**6.15**[78]	**6.06**[85]
Basswood:									
1907	6.68[127]	5.80[20]	6.25[18]	4.96[27]	8.31[21]	7.59[41]	10.21[54]	9.59[27]	10.83[27]
1912	**7.68**[245]	**6.04**[48]	**7.56**[23]	**6.90**[25]	**8.51**[88]	**8.14**[61]	**11.43**[102]	**11.59**[59]	**11.22**[43]
Elm:									
1907	4.74[76]	3.00[7]	4.65[10]	4.07[15]	5.07[14]	5.35[30]	7.42[89]	7.11[37]	7.64[52]
1912	**5.40**[133]	**3.71**[26]	**5.25**[8]	**4.25**[12]	**6.17**[56]	**5.93**[31]	**8.59**[154]	**9.43**[76]	**7.78**[78]
Ash:									
1907	7.99[154]	6.38[26]	8.20[22]	6.29[28]	8.91[23]	9.15[55]	14.19[89]	13.01[39]	15.11[50]
1912	**8.35**[253]	**6.60**[56]	**9.85**[26]	**7.48**[23]	**8.97**[77]	**8.80**[71]	**15.54**[159]	**15.87**[78]	**15.23**[81]

Species and year.	Southern Appalachian States.						
	Average of six States.	Maryland.	Virginia.	West Virginia.	Kentucky.	Tennessee.	North Carolina.
Maple:							
1907	$2.87[103]	$3.14[7]	$2.71[14]	$1.99[26]	$3.41[29]	$3.05[15]	$3.25[12]
1912	**3.68**[138]	**5.31**[16]	**2.70**[5]	**2.78**[9]	**4.01**[37]	**8.84**[22]	**3.09**[49]
Birch:							
1907	2.47[53]	3.17[3]	2.75[8]	2.42[26]	2.25[4]	2.30[5]	2.29[7]
1912	**2.81**[70]	**4.05**[9]	**3.00**[7]	**2.86**[7]	**3.00**[15]	**2.31**[8]	**2.70**[24]
Beech:							
1907	2.24[105]	3.90[6]	2.61[9]	1.67[35]	2.41[38]	2.36[16]	2.00[2]
1912	**2.72**[141]	**3.38**[13]	**2.12**[8]	**1.83**[9]	**3.34**[49]	**2.45**[38]	**2.27**[24]
Basswood:							
1907	3.75[73]	4.50[3]	3.33[6]	3.91[43]	4.46[3]	4.04[12]	1.67[6]
1912	**4.16**[82]	**4.50**[4]	**6.33**[3]	**4.11**[9]	**4.62**[25]	**4.22**[18]	**3.30**[23]
Elm:							
1907	3.04[53]	4.50[2]	2.17[6]	2.19[8]	3.82[24]	2.29[13]	....
1912	**3.51**[79]	**4.56**[8]	**2.67**[3]	**3.00**[1]	**4.09**[29]	**2.80**[33]	**3.70**[5]
Ash:							
1907	5.08[152]	6.42[6]	4.51[20]	5.05[39]	6.38[38]	4.91[27]	3.23[22]
1912	**5.50**[168]	**7.39**[9]	**6.06**[8]	**3.85**[7]	**5.98**[45]	**6.01**[53]	**4.23**[46]

FIG. 1.—CARLOADS OF SPLIT BODY WOOD AND SMALL ROUND WOOD.

FIG. 2.—PEELING STEAMED HARDWOOD BOLTS.

Practically all the species are used except the oaks, hickories, chestnut, and white ash.

NORTHERN HARDWOODS FOR PAPER MANUFACTURE IN PENNSYLVANIA.

TABLE 12.—*Average stumpage values of northern hardwoods for 1907 and 1912*—Contd.

Species and year.	Lake States.								
	Average of three States.	Michigan.				Wisconsin.			Minnesota.
		State average.	Upper peninsula.	Lower peninsula.	Southern tier of counties.	State average.	Northern counties.	Southern counties.	
Maple:									
1907	$3.63[156]	$4.17[92]	$1.91[22]	$4.55[64]	$8.50[6]	$2.71[60]	$2.61[57]	$4.67[3]	$5.13[4]
1912	**5.41**[208]	**6.75**[84]	....	....	....	**3.48**[104]	....	....	**9.86**[20]
Birch:									
1907	4.50[167]	4.95[89]	3.24[23]	5.49[64]	7.29[2]	3.94[66]	....	....	4.29[12]
1912	**5.44**[194]	**6.34**[61]	....	....	....	**4.86**[111]	....	....	**5.84**[22]
Beech:									
1907	3.02[82]	3.11[75]	1.42[6]	2.89[63]	7.17[6]	2.00[7]	....	....	....
1912	**4.54**[92]	**4.79**[78]	....	....	....	**3.17**[14]	....	....	....
Basswood:									
1907	7.42[163]	8.26[88]	5.61[23]	8.95[59]	11.67[6]	6.59[65]	....	....	5.50[10]
1912	**8.02**[247]	**9.57**[86]	....	....	....	**7.12**[122]	....	....	**7.41**[39]
Elm:									
1907	6.10[172]	7.49[87]	4.03[19]	8.34[62]	9.67[6]	4.72[76]	....	....	4.22[9]
1912	**6.61**[227]	**8.77**[82]	....	....	....	**5.01**[112]	....	....	**6.70**[33]
Ash:									
1907	6.49[156]	7.24[90]	4.64[21]	7.67[63]	11.83[6]	5.43[59]	....	....	5.79[7]
1912	**6.85**[195]	**8.72**[71]	....	....	....	**5.38**[99]	....	....	**7.36**[25]

NOTE.—These figures are averages of estimates by timberland owners. The small numerals indicate the number of reports on which the averages are based. In the case of Michigan and Wisconsin, stumpage values in different parts of the States are shown for 1907 to indicate the effect of differences in accessibility upon stumpage values. Similar data were not obtained for 1912. The 1907 data are, of course, obsolete, and illustrate nothing except tendencies. Averages of actual sales of stumpage in 1912 are shown for these regions in Bulletin 152, "The Eastern Hemlock," Table 10.

MANAGEMENT.

THE PLACE OF THE NORTHERN HARDWOODS IN FOREST MANAGEMENT.

The practice of forestry by private owners is practicable in the case of certain quick-growing, valuable species, or, where wood in small sizes is in steady demand, for slower-growing species under short rotations, or on estates maintained for recreation, hunting, or park purposes, in which the cost of maintenance is not charged against the stumpage value. In the case of the northern hardwoods, however, management is, for the present at least, largely a matter of Federal, State, or municipal, rather than of private, concern. The need for such a supply can hardly be questioned. Softwoods will, of course, always be in greater demand, but for furniture, flooring, and finish, veneer, distillation, "novelties," and other uses for which the various northern hardwoods are peculiarly fitted, there will undoubtedly always be a market. The use of substitutes for wood and the importation of foreign hardwoods may retard increase in value; but in spite of a decrease in per capita consumption, the total demand may be expected to tax the capacity of a reduced forest area to supply it.

The agricultural value of much of the land now in hardwoods will cause it eventually to be cleared and tilled. This is especially true in the gentle topography of the Lake States. But the progress of development is a gradual one, and in the meantime the soil might profitably be kept in timber. Ultimately the forests, especially those of northern hardwoods, will be rather closely confined to mountain regions. The hardwood forests of the future will probably share with spruce and fir the narrow mountain valleys and slopes at moderate altitudes, where they will serve at once for steam-flow protection and timber supply. Ridge tops and higher altitudes in the mountain and dry, poor, sandy soils elsewhere are better fitted for softwood than for hardwood management.

Large bodies of old-growth northern hardwoods still remain under private ownership. From the standpoint of growth these represent idle capital, since they have long passed the age of rapid volume increment, and in many cases their growth is offset by decay. The holding of these for increase in stumpage value is of doubtful wisdom in view of deterioration, fire risk, insect damage, etc., and especially the rapidly accumulating interest and tax charges. The owner has, therefore, every incentive to cut his timber and dispose of the land. With very little trouble such lands, when not put into farms, could be protected from fire and allowed to restock with "active capital" in the form of vigorous young growth. Under Federal and State action fire protection is rapidly becoming effective in many parts of the region and thrifty stands of second-growth now occupy soils which in earlier years would have been charred and barren.

OBJECTS OF MANAGEMENT.

The northern hardwood forest region includes such a wide variety of species, markets, climate, and topography that nearly all the recognized systems of management have their place, and none is generally applicable. For any particular tract the system used will depend also upon the object of management. This is often twofold, as when the forest affords both watershed protection and a timber supply.

Ideally, forest management aims to secure the heaviest possible sustained yield of the best species. Practically, it can approach this ideal only so closely as is warranted by the cost of logging and the value of the product. The degree of the compromise varies with these two factors, and the possibilities are therefore greater in some regions than in others. Just as the rise in stumpage value warrants the private holding of timber as an investment under certain conditions, it may also, in extreme cases, warrant the public holding of forests until the time is ripe for more intensive management.

Two considerations, however, point to the general advisability of the early removal of the old-growth timber. These are (1) the risk of loss by fire, insects, decay, wind, or other cause, of the stored-up growth of centuries, and (2) the advantage of placing the stand on an active, producing, instead of an idle, nonproducing basis. The problem of management then becomes how best to dispose of the old growth so as to secure the most desirable composition of the ensuing stand of young growth. Before making cuttings the species which are to be favored in securing reproduction must be decided upon.

CHOICE OF SPECIES.

Wherever possible, a mixture of hardwoods and conifers is desirable. Mixed forests produce heavier yields of better quality, are more effective for watershed protection, and present less risk of total loss from various sources than pure forests. From the standpoint of aggressiveness conifers are not as a rule a menace to the supremacy of hardwoods on fertile soils. To secure natural softwood growth among hardwoods is, in fact, usually a difficult matter, requiring a high degree of technical skill. Red spruce, hemlock, and white pine are the best species to grow among hardwoods.

Of the hardwoods, white ash, basswood, elms, black birch, yellow birch, and red oak are to be favored when in mixture with the more tolerant beech and sugar maple. Beech is usually the least valuable of the species, commercially, so that where possible it should be eliminated and its place given to better species. Its silvicultural value is high, but so closely resembles that of sugar maple that ordinarily no object is gained in keeping it in stands containing both. Sugar maple is the easiest of the intensive species to perpetuate in management. Its reproductive aggressiveness is such that in many regions it will probably be necessary to discourage it in favor of softwoods and preferred hardwoods. The birches are of great present and prospective value, commercially, and their forest value is hardly less than that of beech and maple. Their maintenance in the stand should, therefore, be one of the objects of silviculture wherever the climate and soils are favorable. In the Lake States and at lower altitudes in the mountains the intolerant species—ash, basswood, elm, and red oak—should be given every advantage. As in the natural forest, these will require a commanding position in the crown cover.

The most desirable composition of the stand will be determined chiefly by the climate and market conditions. In general it will comprise a shady, tolerant understory and an intolerant overstory of the most valuable species, hard and soft. The understory will consist largely of sugar maple, but with as much yellow or black birch as can be secured, and possibly a subordinate growth of red spruce or hemlock. The overstory will be of ash, basswood, white pine, or elm, or of any combination of these that the climate permits and the local demand indicates. Where black cherry, red oak, walnut, or other valuable intolerant species are available, these should be favored. Together with ash they are best managed in small, exclusive groups among the other species.

SILVICULTURAL METHODS.

It is impracticable to discuss in detail all the possible methods of management. The method to be chosen depends not only upon the kind of timber present, but also upon the kind of logging, the market conditions, etc. Any method would probably have to conform to local logging practice. In every case the management should follow in general some definite, if elastic, plan prepared in advance. While every stand presents its own problems, there are certain generally applicable procedures which are dealt with in the following discussion from a strictly silvicultural point of view, the many economic factors being neglected.

The most marked differences in silviculture are in the methods employed in old-growth and "second-growth" forests.

Old growth.—The aim of silviculture in old-growth stands, as has already been pointed out, is to replace mature and unproducing with immature, producing timber in such a way as to maintain a sustained periodic (though not necessarily annual) yield, and, at the same time, improve the composition of the stand in the direction indicated under "Choice of species," page 35. This implies a more or less gradual removal of the mature stand. For silvicultural as well as economic reasons, however, the removal must often be accomplished in a single cutting. The management will, therefore, approach two extremes: Clear cutting, after which the management will be that applied to second-growth stands; and the selection system, which is the nearest to nature's method of general replacement in virgin stands. Between these extremes are the seed tree and the shelterwood systems.

Clear cutting is justified silviculturally when there is good promise of seedling or sprout reproduction of desired species. The season in which the cutting is done is, therefore, of importance. Thus by cutting during a heavy seed year of a preferred and an "off" year of an undesirable species it may be possible to control or modify the character of the reproduction. This may also be done by cutting early or late in the year, to avoid or take advantage of the season's seed crop of a given species. Clear cutting may extend over a large area in a single season, the stand supplying its own seed for reproduction, or be confined to a strip along the border of the stand, whence the area is seeded down. In stands containing basswood, clear cutting is usually followed by a vigorous growth of basswood sprouts which far outstrip all other vegetation (Pl. IX). Since basswood will sprout, and apparently with success, from very large stumps, clear cutting seems well adapted to the perpetuation of basswood, even in the virgin stands. It is the simplest and easiest method, as well as the cheapest, from the standpoint of logging; but it converts the forest immediately from an uneven-aged old growth to an even-aged young growth form, which may not be desirable if it is planned to perpetuate the stands on a long rotation basis, and especially if it is to serve partially for soil or stream-flow protection.

To provide against failure of the reproduction because of fire or for some other reason, seed trees may be left. The ordinary rules regarding the selection of seed trees should be observed. These should be thrifty specimens of the desired species, well rooted to lessen danger from windthrow. Short trees with full crowns have correspondingly large root systems, and such should therefore be left for seed supply. Where more slender trees are chosen, they should be left in groups for mutual protection. The number left per acre depends upon the species and the location. To secure an immediate heavy seeding, two or three individuals or small groups of the light-seeded species (birch, elm, ash, etc.) should be left per acre; more trees are necessary for basswood, oak, etc.

The plan of management may contemplate either the abandonment of the seed trees, in which case their stumpage value must be charged against the cost of the natural reproduction established, or their removal in a subsequent logging operation. It may even be planned to leave them as "standards," until the succeeding crop of "second growth" is logged. The risk from wind, insects, disease, etc., makes it advisable in any event to charge the value of the seed trees against the cost of reproduction. The unavoidable damage to young growth caused by removing the seed trees may be an item of some importance. Furthermore, the stumpage value of the seed trees may be close to the cost of planting the area with some desirable species. The alternative of planting should always, therefore, be considered before deciding to leave seed trees.

The selection method is very well adapted to hardwood forests from a silvicultural but not from a logging point of view. The removal of carefully selected trees uniformly throughout the stand affords an excellent means of controlling the subsequent composition, and insures a sustained yield of increasing quality. But the trees removed will at first be of inferior value, probably too low to pay logging costs. Only a small percentage of the total volume of the stand will be removed at one time, and the trees will be so scattered that many roads will be necessary and handling charges will be very heavy. At the same time, this system is a difficult one to operate, requiring technical attention of a high grade. In its ideal form, therefore, the selection system is not yet applicable in this country to large tracts of hardwood timber, except when the management involves some other object than money returns.

A practical modification of the selection system which has been recommended for northern hardwood management involves a cutting to a minimum diameter limit, which is not fixed but varies according to the average size of the timber and is higher for preferred and lower for inferior species. To make logging financially possible, the cutting must be rather heavy and at rather long intervals. It is thus impossible to control the species in the reproduction by regulating the light supply. On the other hand, this compromise is about the only one by which a sustained periodic yield could be at once provided for.

Under many conditions the selection group method is the best that could be practiced. This is true particularly for stands containing intolerant species, whose reproduction may be favored by removing small groups of trees in the vicinity of the seed trees. Groups of intolerant seedlings, already started, may be freed in this way. White ash is a species well fitted for management by this method.[1]

Two important considerations in management are the material which it is aimed to produce and the rotation necessary to produce it. Under silviculture the volume growth per acre may be expected to be much greater than the average in the virgin forest, equal at least, to the maximum shown in Tables 7 to 9. To ascertain what might be expected of beech under management, the most rapid diameter-growth rates for each one-half inch in radius of the beech trees on which the growth values in Tables 7 to 9 are based were selected and averaged by a curve.[2] The resulting "selective" growth rate, with the per cent by which it exceeds the maximum, is shown in Table 13.

TABLE 13.—*Selective maximum diameter growth of Michigan beech.*

Age.	Diameter breast-high.		Age.	Diameter breast-high.	
	Composite of maximum decades.	Excess over maximum in Table 7.		Composite of maximum decades.	Excess over maximum in Table 7.
Years.	*Inches.*	*Per cent.*	*Years.*	*Inches.*	*Per cent.*
10	0.5	....	70	13.1	102
20	1.9	46	80	15.2	103
30	3.8	65	90	17.3	101
40	5.9	79	100	19.1	99
50	8.3	89	110	20.8	92
60	10.7	98			

Somewhat similar results are obtainable for other species. Trees in the open undoubtedly grow even faster than this, but it is at the expense of the long, clear log lengths of forest-grown trees. This accelerated growth represents an ideal to be approached under management in which each tree would receive from youth up just the

[1] See Department of Agriculture Bulletin 299. "The ashes: Their characteristics and management," by W. D. Sterrett.

[2] This process was devised and applied by W. B. Barrows.

right amount of light for the most rapid growth consistent with good trunk development and the complete utilization of all sunlight by the aggregate crown cover. In the selection forest, growth at this rate can not be expected for all the trees all the time. Thinnings, heavy enough to permit rapid growth of the younger trees, would sacrifice a great deal of immediate volume increment per acre of the larger timber. In fairly even-aged timber managed under the shelter-wood system, however, the accelerated growth might be more nearly maintained for all individuals by judicious thinning.

Young growth under virgin stands must usually be sacrificed in logging. There is little use in attempting to save it, since much of it has been so suppressed by shade that it is less vigorous than a new growth would be. If left exposed by the removal of much of the large timber, it would probably suffer great damage from wind, snow, and ice (Pl. XIV, fig. 1). Moreover the logging operations and the subsequent hauling break down a large proportion of the smaller trees, either killing them outright or causing them to lead a crippled existence, occupying valuable space to the exclusion of better trees. It is therefore advisable, in most virgin stands, to cut as cleanly and utilize to as small sizes as possible, thus clearing the way for a vigorous reproduction from the seed trees which are left.

Culled forest.—By culled forest is here meant a forest which has been culled of its best trees, but in which, usually, at least half of the original stand remains (Pl. I). Among the trees commonly culled from hardwood forests are white pine, red spruce, hemlock, bird's-eye maple, curly birch, "whitewood" or yellow poplar, cucumber, cherry, basswood, etc. Forests are often culled several times, a different species being removed each time to fill a special demand. This tends to simplify the composition of the forest, and also to decrease its value, while the power of the more highly prized species to compete with the others in the second growth is curtailed by the decrease in their seed supply.

The openings left by the removal of the scattered trees or groups of trees admit sunlight to the soil, and the openings soon become filled with young trees. These patches of young growth, when fairly abundant, form the basis for the management of the stand. All logging should be conducted with special reference to preserving and extending the stand of young growth. The merchantable timber should not all be removed at a single cutting, but enough of it should be left to warrant a second cutting at a later date. The trees left standing will serve to seed down the soil and fill up most of the gaps between the already existing groups of reproduction. The increased light which the remaining large trees receive will not only increase their seed production, but will accelerate their growth. The second cutting should be made after from 5 to 10 years, when the ground is well stocked with a thrifty reproduction, plentiful enough to be mutually protective.

Care should be taken to remove at the first cutting: (1) Trees of species not wanted in the reproduction, such as beech when in mixture with yellow birch, sugar maple, and other more valuable species; (2) damaged trees, liable to depreciate before a second cutting, and (3) heavy-foliaged, limby trees which shade the ground too thoroughly for successful reproduction and would be apt to damage young growth when removed. Where the reproduction groups are numerous, it will often be necessary to fell trees toward each other so that the damage from their fall may be reduced to a minimum.

As a result of the first cutting, there will thus be left a uniform but rather open stand of sound, well-shaped trees of the best species, interspersed with groups of well-started young growth. The increased light and root space stimulate growth in both the old and the young trees, prepare the soil for seed, and increase the seed supply from the large timber. Within 5 or at most 10 years the reproduction may be expected to be complete over all well-lighted spots. The remaining merchantable trees, now considerably larger owing to their growth since the first cut, are then felled with the greatest care to minimize the damage to the reproduction. If the felling and removal of the first crop is carefully done, such gaps as remain in the reproduction will not be large, and will, in most cases, result in increased growth of the adjacent stand due to the abundant light thus admitted.

Second-growth.[1]—Under this title are included all young hardwood stands, whether they result from the removal of older stands, from fire, or from any other cause. In composition such young stands vary even more greatly than those which preceded them, for they contain great quantities of small, weedlike species, like fire cherry, dwarf maple or "moose maple," aspen, etc., which, on account of their short lives or intolerance of shade, do not remain long in the stand.

Sprouts commonly form a large proportion of the second-growth after logging. They spring abundantly from most hardwood stumps, large or small, but those from large stumps are rarely thrifty, except in the case of basswood and chestnut (Pl. IX). Among them appear various small annual weeds, like "fireweed" (*Erechtites hieracifolia* and *Eupatorium* sp.), blackberry briers, fire cherry and other small trees, and finally forest-tree seedlings. Though not always the last in this succession, seedlings of the desired kinds often find difficulty in growing up through the tangled masses of vegetation which follow clearing (Pl. VI). Thus yellow birch must come in, if at all, within a few years after the land is cleared, or other vegetation will be apt

[1] The management of second-growth hardwoods is discussed in Bulletin 176 of the Vermont Agricultural Experiment Station, Burlington, Vt.

FIG. 1.—PARTIAL CUTTING IN OLD-GROWTH HARDWOODS. McKEAN COUNTY, PA.

Too much of the stand was taken, and the slender trees left were bent or uprooted by snow and ice the following winter. Either more trees should have been left or the stand should have been clear cut, as in fig. 2.

FIG. 2.—CLEAR CUTTING IN SECOND-GROWTH HARDWOODS. CATSKILL MOUNTAINS, N. Y.

TWO WAYS OF CUTTING NORTHERN HARDWOODS FOR CHEMICAL DISTILLATION.

FIG. 1.—HEAVY THINNING IN A 32-YEAR-OLD STAND OF MIXED HARDWOODS.

Slow-growing species were cut and sold for fuel, leaving cherry, ash, and red maple. This is plot No. 18, p. 27.

FIG. 2.—LIGHTLY THINNED YELLOW BIRCH STAND IN NEW HAMPSHIRE; ABOUT 45 YEARS OLD.

THINNINGS IN SECOND-GROWTH STANDS.

to forestall it and shade it out; beech and maple, however, are less exacting. To induce sprout production, the cutting should be done during the season of vegetative rest, from late fall to early spring, and the stumps should be cut low.

In respect to the ultimate size and quality which they attain, seedlings are much superior to sprouts. In beech, as has been seen, sprouts rarely or never attain merchantable size in the North. Maple and birch sprouts, however, like most of the other common hardwoods, often grow rapidly and well to a moderate size, suitable for cordwood. Only the small stumps, 6 inches or less in diameter, should be chosen for sprout production, and wherever possible all but one of the many sprouts which appear on each stump should be removed. Such a thinning will result in the vigorous and rapid growth of the remaining sprout. Basswood is second only to chestnut in sprouting capacity, and sprouts of log size are often found springing from stumps 2 or 3 feet in diameter. (Pl. IX.)

Aside from the cutting of sprouts, the young stand will need little attention for 5 or 10 years. During this time it will have succeeded in killing out most of the blackberry and other competing shrubs, while many of the fire cherry and other short-lived, light-needing species, and even some of the maple and beech saplings, will have been choked out. At this period in its life the young growth commonly forms a dense thicket of slender saplings, 8 or 10 feet high, in which growth is quite slow, owing to the intense crowding. If from one-third to one-half of the young trees are now removed, so as to give more light and growing space to those which remain, the survivors will at once put on foliage and begin to grow vigorously until their crowns once more crowd each other. (Pl. XV, figs. 1 and 2.) The first thinning, which takes out entirely useless material, can be expected to pay for itself only in the increased growth of the stand, hastening the time at which it may be properly cut. Subsequent thinnings, however, besides resulting in rapid growth, produce a merchantable yield which may not only pay for the thinning, but may also give a small profit.

The aim in all thinnings should be to remove enough trees to prevent danger of crowding for several years to come, and at the same time to leave enough trees to utilize fully the increased light and to prevent the growth of grass and weeds on the soil beneath them. Damaged, poorly formed, and small trees should be removed in preference to the more vigorous ones, and the quality of the stand should also be improved by removing the least desirable species.

Wood-distillation factories in the East (notably in the Catskills) have already taken steps toward the management of second-growth hardwoods, and have bought mountain lands in quantities sufficient to supply them perpetually on an estimated yield per acre basis.

The stands are unthinned and are customarily cut clear, the largest timber being the first cut. (Pl. XIV, fig. 2.) With the introduction of thinnings and possibly of the shelterwood system of reproduction cuttings, both the yield and the composition of these stands could be materially improved. In the case of the thinned stand illustrated (Pl. XV, fig. 1) as plot No. 18 (p. 27) the owner realized a substantial profit in addition to a good stumpage value for his thinnings, and at the same time left the stand in a very much better condition as to species and growing space. With improving tax laws and increasing stumpage values, the opportunities for intensive management of second-growth hardwoods can not fail to extend.

APPLICATION OF PRINCIPLES OF MANAGEMENT IN TIMBER-SALE PRACTICE.

The method of applying the principles governing management in any particular region is illustrated in the following provisional schedule of instructions proposed for timber-sale practice on Federal land in the White Mountains of New Hampshire.

Principles Governing the Marking of Northern Hardwoods in National Forest Timber-Sale Practice in the White Mountains.

OBJECTS OF MARKING:

In general, the objects of marking will be:

(1) To secure a reproduction of desirable species.

(2) To remove a practicable cut for the operator under the actual local conditions as to marketable products.

(3) To improve existing stands through the removal for utilization of (*a*) large mature timber; (*b*) smaller trees when decayed, insect infested, or otherwise defective; and (*c*) trees of the less valuable species; and through thinnings to increase the growth of preferred species.

The markings will vary in detail according to the composition of the forest type, the topography, aspect, etc. In general, the following variations in composition may be distinguished:

OLD-GROWTH YELLOW BIRCH, BEECH, AND HARD MAPLE:

(*a*) With mixture of spruce, balsam, or hemlock.
(*b*) With mixture of white pine or tamarack.
(*c*) With mixture of ash, elm, basswood, or red oak.
(*d*) With mixture of paper birch or aspen.
(*e*) With beech predominating.
(*f*) With yellow or black birch predominating.
(*g*) With sugar maple predominating.

YOUNG-GROWTH HARDWOODS (EVEN-AGED):

(*a*) Pure or mixed stands of yellow birch, beech, and maple with and without mixture of conifers, ash, elm, basswood, and oak.

(*b*) Pure or mixed stands of paper birch and aspen, with subordinate conifers or hardwoods.

MARKING IN OLD-GROWTH HARDWOODS:

(*a*) *With mixture of spruce, balsam, or hemlock:*

Wherever practicable, conifers should be encouraged among the hardwoods, to increase the value and size of the future yield and, on watersheds, the protective value of the forest. With tolerant conifers this should be attempted by selection cuttings among the hardwoods, aimed to free the crowns of the conifers. On steep slopes and in exposed situations the cuttings, if done at all, should be very light. Where danger from windthrow is slight the hardwoods should be marked heavily, but the stand should be left sufficiently dense to afford reasonable protection from the wind. The severity of the cutting should be expressed in terms of the crown classes and species to be removed. If preferred, the approximate percentage of the merchantable timber corresponding to the species and crown classes designated for removal may be added. When even-aged groups of small hardwoods or conifers occur among older timber they will be thinned, provided marketable material can be obtained. In groups of small yellow birch, for example, considerable hub and bobbin stock may be available, but care must be taken not to thin too heavily. The same care should be used in thinning groups of small softwoods for pulpwood, etc. Not more than a third of the trees comprising the dominant stand should be removed, together with all the subordinate trees that are merchantable.

Brush should be lopped and scattered.

(*b*) *With mixture of white pine and tamarack:*

As a rule, only widely scattered seedlings of pine or tamarack can be expected to succeed under hardwood shade or in competition with hardwood reproduction. Mature trees of these species should therefore be removed in the first selection or shelterwood cutting. Small or oppressed individuals should be freed and left for increment and whatever scattered reproduction they may succeed in starting.

Brush should be lopped and scattered.

(*c*) *With mixture of ash, elm, basswood, or red oak:*

The light requirements of ash, elm, basswood, and red oak prevent their successful reproduction under heavy shade. Where these species occur in the stand, however, their reproduction should be the main object of management. This can best be accomplished by local shelterwood cuttings. These should remove the stand in two cuttings separated by a period of 10 or 20 years. The first cutting should be heavy, reducing the crown cover fully one-half, removing the trees of all the lower crown classes, and leaving large-crowned trees of the more valuable, less tolerant species to restock.

Brush should be lopped and scattered.

(*d*) *With mixture of paper birch or aspen:*

Where trees of these species occur individually among old-growth hardwoods, they should be removed in the selection cutting in favor of the longer lived species, if a market exists, except where they are not competing strongly, in which case they may, if thrifty, be left for a subsequent cutting. Where birch and aspen form pure groups among hardwoods they may be thinned, if practicable, and the most promising individuals left for a subsequent cutting. If promising reproduction is beneath them, however, such stands should be cut as clean as the possibilities of utilization will permit.

Brush should be lopped and scattered.

(*e*) *Old-growth with beech predominating:*

The object of management should be eventually to replace the beech with some species of greater promise, except on steep slopes, where the cuttings necessary to accomplish this might cause serious erosion. The shelterwood method is best adapted, approaching the clear-cutting-with-seed-trees method where the stand runs especially heavy to beech. If it can be done without loss to the operator, all merchantable beech shall be removed, together with only those trees of other species which are defective or whose presence is unnecessary to preserve the uniformity of the shelterwood, or to serve as seed trees. Where possible, the logging should precede rather than follow a heavy production of beech seeds.

Brush should be lopped and scattered so as to lie close to the ground.

(*f*) *Old-growth with yellow birch predominating:*

The shelterwood method is applicable in stands running largely to birch. The first cutting should remove about 50 per cent of the upper crown cover. The remaining half of the upper crown cover should include the crowns of thrifty yellow birches and less tolerant species like ash, elm, oak, or bass wood, whose reproduction is desirable. Where groups of thrifty young growth of mixed species exist these should be lightly thinned and left for subsequent cutting. The subordinate stand should be removed if merchantable, except that especially thrifty small and large poles, well situated as to light and protection from wind, may be left for a later cut, in the discretion of the marker.

The brush should be lopped and scattered.

(*g*) *Old-growth with sugar maple predominating:*

According to the composition of the stand, the management should follow the principles laid down in (*a*), (*b*), (*c*), or (*d*). In general, the management should aim (1) to eliminate beech and other species of lesser value, (2) to perpetuate sugar maple, or (3) in the presence of more valuable species, to increase their proportion in the stand at the expense of the maple. Provisions aiming to secure (1) and (3) are given above. Maple is the most aggressive reproducer in the forest, of the northern hardwoods. To perpetuate it either the selection or the shelterwood method may be used. The severity of the selection cutting should be expressed in terms of the crown classes and species to be removed. If preferred, the approximate percentage of the merchantable timber corresponding to the species and crown classes to be removed may be added. Unless it increases the danger of windthrow or results in loss to the operator, marking will be lighter in stands containing a large proportion of thrifty young and middle-aged timber, and heavier in stands containing a large proportion of mature and overmature timber; except that on steep slopes the cutting should be very light. When crowded groups of small trees occur among older timber they will be thinned, provided they contain marketable material.

Brush should be lopped and scattered.

YOUNG-GROWTH HARDWOODS (EVEN-AGED):

In young hardwoods, cuttings should be restricted to (1) improvement and increment thinnings in stands of the tolerant, longer-lived species, and in immature stands of intolerant, short-lived species (aspen and paper birch), wherever merchantable material can be removed practicably; and (2) to clear cuttings of aspen and paper birch which have reached physical maturity.

(1) The thinnings should remove (*a*) merchantable defective trees, (*b*) merchantable trees of the less valuable species in the stand, (*c*) not over 50 per cent of the trees comprising the dominant, codominant, and intermediate crown classes, and (*d*) all merchantable trees of the subordinate crown classes. The degree of thinning should depend upon the stem density of the stand and the consequent degree of windfirmness which the individuals will be likely to possess when the stand is opened up. This must be judged on the ground by the person conducting the marking.

Brush should be lopped and scattered.

(2) To reproduce these stands *in situ* early spring clear cutting should be practiced. Aspen root suckers and birch stump sprouts which result will probably grow rapidly enough to take care of themselves if the competing hardwood growth is not too abundant. Where a desirable reproduction of conifers or hardwoods exists, all merchantable birch and aspen should be removed, with care to prevent damage to the reproduction.

Brush should be lopped and scattered.

SPECIES MENTIONED IN THIS BULLETIN.

Alders	*Alnus* sp.
Arborvitæ	*Thuja occidentalis* Linn.
Ash, black	*Fraxinus nigra* Marsh.
Ash, white	*Fraxinus americana* Linn.
Aspen	*Populus tremuloides* Michx.
Aspen, large tooth	*Populus grandidentata* Michx.
Balm of Gilead	*Populus balsamifera* Linn.
Balsam fir. (See Fir.)	
Basswood	*Tilia americana* Linn.
Beech	*Fagus atropunicea* (Marsh) Sudworth.
Birch, black ("sweet," "cherry")	*Betula lenta* Linn.
Birch, gray ("white")	*Betula populifolia* Marsh.
Birch, paper ("white," "canoe")	*Betula papyrifera* Marsh.
Birch, yellow ("gray," "red," "silver")	*Betula lutea* Michx. f.
Cherry, black	*Prunus serotina* Ehrh.
Cherry, fire ("pin," "wild red")	*Prunus pennsylvanica* Linn. f.
Chestnut	*Castanea dentata* (Marsh) Borkh.
Cucumber tree	*Magnolia acuminata* Linn.
Elm, cork ("rock," "hard")	*Ulmus racemosa* Thomas.
Elm, slippery ("red")	*Ulmus pubescens* Walt.
Elm, white ("gray," "soft")	*Ulmus americana* Linn.
Fir, balsam	*Abies balsamea* (Linn.) Mill.
Gum, black ("sour")	*Nyssa sylvatica* Marsh.
Gum, red ("sweet")	*Liquidambar styraciflua* Linn.
Hemlock	*Tsuga canadensis* (Linn.) Carr.
Hickory	*Hicoria* sp.
Ironwood ("hornbeam")	*Ostrya virginiana* (Mill.) Koch.
Magnolia	*Magnolia* sp.
Maple, black	*Acer saccharum nigrum* (Mich. f.) Britton.
Maple, red	*Acer rubrum* Linn.
Maple, silver	*Acer saccharinum* Linn.
Maple, striped ("moosewood")	*Acer pennsylvanicum* Linn.
Maple, sugar	*Acer saccharum* Marsh.
Oak, red	*Quercus rubra* Linn.
Oak, white	*Quercus alba* Linn.
Pine, jack	*Pinus divaricata* (Ait.) Du Mont de Cours.
Pine, norway ("red")	*Pinus resinosa* Ait.
Pine, white	*Pinus strobus* Linn.
Poplar, yellow ("tulip")	*Liriodendron tulipifera* Linn.
Poplar. (*See* Aspens and Balm of Gilead).	
Spruce, black	*Picea mariana* (Mill.) B. S. P.
Spruce, red	*Picea rubens* Sargent.
Spruce, white	*Picea canadensis* (Mill.) B. S. P.
Sycamore	*Platanus occidentalis* Linn.
Tamarack ("larch")	*Larix laricina* (Du Roi) Koch.
Walnut	*Juglans* sp.
Willows	*Salix* sp.

APPENDIX.[1]

VOLUME TABLES.

BOARD-FOOT VOLUMES.

The following tables give the average volumes in board feet of forest-grown beech, basswood, yellow birch, and sugar maple trees of different sizes, in terms of the number of possible 16-foot logs and half logs in the tree. Since among trees of the same size some will be straight and usable to a small diameter at the top, while others break up into branches at considerably larger diameters, the Lake States measurements were separated on this basis, and appear in three tables, headed maximum, average, and minimum utilization. The tables from the other regions represent only the average utilization.

The tables were prepared by the Scribner Decimal C rule, and show in each case the stump height, top diameter limit, and number of trees on which they are based. "Diameter breast-high" is the diameter at a height of 4½ feet. The tables are based on measurements of sound trees of normal shape only.

TABLE 14.—*Yellow birch in New Hampshire,*[1] *volumes in board feet.*

Diameter breast-high.	Number of 16-foot logs.							Diameter inside bark of top.	Stump height.	Basis.
	½	1	1½	2	2½	3	3½			
	Volume—board feet in tens.									
Inches.								*Inches.*	*Feet.*	*Trees.*
7	1	1	2	3	......	......	......	6	2.1	2
8	1	2	2	3	4	......	......	6	2.1	8
9	1	2	3	4	5	......	......	7	2.2	24
10	2	3	4	5	6	......	......	7	2.2	43
11	2	4	5	6	8	......	......	8	2.2	44
12	3	5	6	8	9	......	......	8	2.2	45
13	3	6	8	9	11	......	......	9	2.2	36
14	4	7	9	11	13	14	......	9	2.3	35
15	4	8	11	13	15	16	......	10	2.3	47
16	5	10	13	15	17	18	......	11	2.3	40
17	6	11	15	18	20	21	......	11	2.4	32
18	7	13	17	20	23	25	......	12	2.4	38
19	8	14	20	23	26	28	......	13	2.4	36
20	9	16	22	26	30	33	36	13	2.5	39
21	10	18	25	30	34	37	41	14	2.5	28
22	11	20	27	33	38	42	47	15	2.6	21
23	13	23	30	36	42	48	53	15	2.6	24
24	14	25	33	40	47	53	59	16	2.7	21
25	15	27	36	44	51	58	64	16	2.7	23
26	......	30	40	48	56	63	70	17	2.8	17
27	......	33	44	52	61	69	76	18	2.9	14
28	......	36	48	57	66	74	82	18	2.9	17
29	......	......	52	62	71	80	88	19	3.0	7
30	......	......	57	67	77	86	95	20	3.0	....
31	......	......	......	72	82	92	101	20	3.1	5
32	......	......	......	78	88	98	108	21	3.1	5
										651

[1] Grafton County.

Logs scaled as cut, 10 to 16 feet long, by Scribner Decimal C rule. Utilization as close as form of tree allowed.

[1] Credit is due to W. B. Barrows, of the Forest Service, for the working up from field data of all the tables in the Appendix not credited to other sources.

TABLE 15.—*Yellow birch in the Lake States,*[1] *volumes in board feet.*

AVERAGE TOP DIAMETERS.

Diameter breast-high.	Number of 16-foot logs.					Diameter inside bark of top.	Basis.
	1½	2	2½	3	3½		
	Volume—board feet.						
Inches.						*Inches.*	*Trees.*
8	23	37	....	....	....	6	11
9	30	45	....	....	....	6	17
10	36	54	72	92	....	6	26
11	43	63	84	100	....	6	17
12	50	73	97	120	....	7	27
13	57	83	110	140	170	7	20
14	65	94	130	160	190	7	16
15	73	110	140	180	210	8	8
16	82	120	160	200	240	8	16
17	....	140	180	230	270	9	15
18	....	160	210	260	300	9	15
19	....	180	230	290	340	10	13
20	....	200	270	330	380	10	9
21	....	230	300	370	430	11	6
22	....	260	340	410	490	12	3
23	....	290	380	460	550	12	5
24	....	330	430	510	610	13	4
25	....	360	470	570	680	14	4
26	....	400	520	630	750	15	2
27	....	440	570	690	830	15	....
28	....	480	620	760	900	16	1
29	....	520	670	830	980	17	2
30	....	560	720	900	1,050	17	....
							237

[1] Gogebic and Wexford Counties, Mich.; Marinette and Vilas Counties, Wis.

Scaled from taper curves by Scribner Decimal C rule; mostly in 16.3-foot logs, with a few shorter logs where necessary. Stump height, 1 foot. Average utilization.

TABLE 16.—*Yellow birch in the Lake States,*[1] *volumes in board feet.*

MINIMUM TOP DIAMETERS.

Diameter, breast-high.	Number of 16-foot logs.						Diameter inside bark of top.	Basis.
	2	2½	3	3½	4	4½		
	Volume—board feet.							
Inches.							*Inches.*	*Trees.*
8	32	43	55	....	....	....	6	11
9	40	52	66	....	....	....	6	17
10	49	62	78	95	....	....	6	26
11	58	73	90	110	....	....	6	17
12	69	85	100	130	140	....	6	27
13	81	98	120	140	160	....	6	20
14	94	110	130	160	180	....	6	16
15	....	130	150	180	210	240	6	8
16	....	150	170	200	230	270	6	16
17	....	....	190	230	260	300	6	15
18	....	....	220	250	290	330	6	15
19	....	....	240	280	330	370	6	13
20	....	....	270	320	360	410	6	9
21	....	....	310	360	410	460	7	6
22	....	....	350	400	450	510	7	3
23	....	....	390	450	500	560	8	5
24	....	....	440	500	560	620	8	4
25	....	....	480	550	620	690	9	4
26	....	....	540	610	690	760	10	2
27	....	....	590	670	760	840	10	....
28	....	....	650	740	830	920	11	1
29	....	....	710	820	920	1,010	12	2
30	....	....	780	890	1,010	1,100	13	....
								237

[1] Gogebic and Wexford Counties, Mich.; Marinette and Vilas Counties, Wis.

Scaled from taper curves by Scribner Decimal C rule; mostly in 16.3-foot logs, with a few shorter logs where necessary. Stump height 1 foot. Close utilization.

TABLE 17.—*Yellow birch in the Lake States,*[1] *volumes in board feet.*

MAXIMUM TOP DIAMETERS.

Diameter, breast-high.	Number of 16-foot logs. 1	1½	2	Diameter inside bark of top.	Basis.
	Volume—board feet.				
Inches.				*Inches.*	*Trees.*
8	23	....	....	7	11
9	28	....	....	7	17
10	33	51	....	8	26
11	39	62	....	8	17
12	45	75	110	9	27
13	52	87	120	10	20
14	60	100	140	10	16
15	68	120	150	11	8
16	78	130	170	12	16
17	88	150	190	12	15
18	98	170	210	13	15
19	110	190	240	14	13
20	120	210	260	14	9
21	140	240	290	15	6
22	150	270	320	16	3
23	170	300	360	17	5
24	190	330	400	17	4
25	210	360	450	18	4
26	230	400	500	19	2
27	260	440	550	19	....
28	280	480	600	20	1
29	310	520	650	21	2
30	340	570	710	22	....
					237

[1] Gogebic and Wexford Counties, Mich.; Marinette and Vilas Counties, Wis.

Scaled from taper curves by Scribner Decimal C rule; mostly in 16.3-foot logs, with a few shorter logs where necessary. Stump height 1 foot. Poor utilization.

TABLE 18.—*Beech in New Hampshire,*[1] *volumes in board feet.*

Diameter, breast-high.	Number of 16-foot logs. ½	1	1½	2	2½	3	3½	Diameter inside bark of top.	Stump height.	Basis.
	Volume—board feet in tens.									
Inches.								*Inches.*	*Feet.*	*Trees.*
7	1	1	2	......	......	......	......	6	1.8	1
8	1	2	3	......	......	......	......	6	1.8	3
9	2	3	4	5	......	......	......	7	1.9	4
10	2	4	5	6	......	......	......	8	1.9	11
11	3	4	6	8	9	......	......	8	2.0	24
12	3	6	8	9	11	......	......	9	2.0	35
13	4	7	9	11	13	15	......	10	2.0	45
14	5	8	11	13	16	18	......	11	2.1	41
15	6	10	13	16	19	21	24	11	2.1	45
16	......	11	15	19	22	26	29	12	2.1	43
17	......	13	17	22	26	30	34	13	2.2	37
18	......	......	20	26	30	35	39	13	2.2	28
19	......	......	23	30	35	40	44	14	2.2	10
20	......	......	......	34	39	44	49	15	2.2	18
21	......	......	......	38	44	49	54	15	2.2	11
22	......	......	......	42	48	53	59	16	2.3	11
23	......	......	......	46	52	58	64	17	2.3	8
24	......	......	......	49	56	62	69	17	2.3	1
										376

[1] Grafton County.

Logs scaled as cut, 10 to 16 feet long, by the Scribner Decimal C rule. Utilization as close as form of tree allowed.

TABLE 19.—*Beech in Pennsylvania,*[1] *volumes in board feet.*

Diameter, breast-high.	Number of 16-foot logs.					Diameter inside bark of top.	Basis.
	2	2½	3	3½	4		
	Volume—board feet.						
Inches.						*Inches.*	*Trees.*
10	47	67	87	110	....	6	14
11	52	77	100	130	....	7	6
12	61	91	120	150	170	7	6
13	74	110	140	170	200	7	8
14	92	130	170	200	230	8	11
15	120	160	200	230	270	8	5
16	150	190	230	270	310	9	13
17	180	220	270	310	360	9	10
18	220	260	310	350	410	10	10
19	....	290	350	400	460	11	11
20	....	330	390	450	510	11	5
21	....	370	430	500	570	12	6
22	....	400	470	560	640	13	2
23	....	440	520	610	710	14	5
24	....	490	570	670	780	15	2
25	....	530	620	740	870	16	1
26	....	....	670	810	960	17	1
27	....	....	720	890	1,050	18	....
28	....	....	780	960	1,150	19	....
29	....	....	830	1,040	1,260	20	1
30	....	....	880	1,120	1,370	21	1
							118

[1] McKean County.

Height of stump, 1.5 to 3.3 feet. Scaled by the Scribner Decimal C rule.

TABLE 20.—*Beech in Michigan,*[1] *volumes in board feet.*

AVERAGE TOP DIAMETERS.

Diameter, breast-high.	Number of 16-foot logs.								Diameter inside bark of top.	Basis.
	1	1½	2	2½	3	3½	4	4½		
	Volume—board feet.									
Inches.									*Inches.*	*Trees.*
6	16	25	34	43	53	....	....	....	6	2
7	17	27	37	48	62	....	....	....	6	13
8	18	29	41	55	71	89	....	....	6	20
9	20	32	46	63	81	100	....	....	6	11
10	22	37	52	72	93	110	130	....	6	23
11	24	42	60	83	110	130	160	....	6	22
12	26	47	69	96	120	150	180	210	7	30
13	28	53	80	110	140	180	210	240	7	19
14	30	60	93	120	160	200	240	280	7	25
15	33	68	110	140	180	230	270	310	8	26
16	36	77	120	160	210	250	300	350	8	28
17	....	85	140	190	240	290	340	400	9	14
18	....	95	160	210	270	320	390	450	9	14
19	....	110	180	240	310	370	430	500	10	9
20	....	....	200	280	350	420	490	560	10	6
21	....	....	220	320	390	470	550	630	11	7
22	....	....	250	360	440	530	620	710	12	8
23	....	....	....	400	500	600	690	800	12	4
24	....	....	....	440	560	670	780	890	13	3
25	....	....	....	....	620	740	860	1,000	14	1
26	....	....	....	....	680	820	960	1,110	15	....
										285

[1] Wexford County.

Scaled from taper curves, by the Scribner Decimal C rule, mostly in 16.3-foot logs, with a few shorter logs. Stump height, 1 foot. Average utilization.

TABLE 21.—*Beech in Michigan,*[1] *volumes in board feet.*

MINIMUM TOP DIAMETERS.

Diameter, breast-high.	Number of 16-foot logs.									Diameter inside bark of top.	Basis.
	1	1½	2	2½	3	3½	4	4½	5		
	Volume—board feet.										
Inches.										*Inches.*	*Trees.*
6	16	25	34	......	......	......	......	......	......	6	2
7	17	27	37	......	......	......	......	......	......	6	13
8	18	29	41	55	......	......	......	......	......	6	20
9	19	31	44	60	77	......	......	......	......	6	11
10	20	33	48	66	86	100	......	......	......	6	23
11	21	35	54	73	96	120	140	......	......	6	22
12	22	38	60	81	110	130	160	210	......	6	30
13	......	40	66	89	120	150	190	230	......	6	19
14	......	43	73	98	130	170	210	260	......	6	25
15	......	......	81	110	150	190	230	280	330	6	26
16	......	......	90	120	170	210	260	310	360	6	28
17	......	......	......	130	180	230	290	340	390	6	14
18	......	......	......	140	200	260	320	370	430	6	14
19	......	......	......	......	230	300	360	420	470	6	9
20	......	......	......	......	250	340	410	470	530	6	6
21	......	......	......	......	......	390	460	530	600	7	7
22	......	......	......	......	......	450	520	600	670	7	8
23	......	......	......	......	......	520	590	670	750	8	4
24	......	......	......	......	......	590	670	760	850	8	3
25	......	......	......	......	......	660	750	850	950	9	1
26	......	......	......	......	......	750	850	940	1,040	10	......
											285

[1] Wexford County.

Scaled from taper curves, by the Scribner Decimal C rule, mostly in 16.3-foot logs, with a few shorter logs. Stump height, 1 foot. Close utilization.

TABLE 22.—*Beech in Michigan,*[1] *volumes in board feet.*

MAXIMUM TOP DIAMETERS.

Diameter, breast-high.	Number of 16-foot logs.					Diameter, inside bark of top.	Basis.
	1	1½	2	2½	3		
	Volume—board feet.						
Inches.						*Inches.*	*Trees.*
6	20	27	......	......	......	6	2
7	22	32	41	......	......	6	13
8	24	37	52	68	......	7	20
9	27	44	63	83	110	7	11
10	32	53	75	97	120	8	23
11	36	63	88	110	140	8	22
12	42	74	100	130	160	9	30
13	48	87	120	150	190	10	19
14	56	100	140	180	210	10	25
15	65	120	160	200	250	11	26
16	75	130	180	230	280	12	8
17	87	150	210	270	330	12	14
18	98	170	240	300	370	13	14
19	130	190	270	340	420	14	9
20	140	220	300	380	470	14	6
21	......	240	340	430	520	15	7
22	......	270	380	480	580	16	8
23	......	300	420	530	650	17	4
24	......	......	460	590	730	17	3
25	......	......	500	660	820	18	1
26	......	......	540	730	920	19	......
							285

[1] Wexford County.

Scaled from taper curves, by the Scribner Decimal C rule, mostly in 16.3-foot logs, with a few shorter logs. Stump height, 1 foot. Poor utilization.

TABLE 23.—*Sugar maple in New Hampshire,*[1] *volumes in board feet.*

Diameter, breast-high.	Number of 16-foot logs. ½	1	1½	2	2½	3	3½	4	Diameter, inside bark of top.	Height of stump.	Basis.
	Volume—board feet in tens.										
Inches.									*Inches.*	*Feet.*	*Trees.*
7	1	1	2	......	......	......	......	......	6	2.0	1
8	1	2	2	3	......	......	......	......	6	2.0	3
9	2	2	3	4	5	......	......	......	7	2.0	3
10	3	3	4	5	6	7	......	......	7	2.0	13
11	4	4	5	7	8	9	......	......	8	2.1	18
12	4	5	7	8	9	11	12	......	8	2.1	25
13	5	7	8	10	11	13	14	......	9	2.1	24
14	6	8	9	11	13	15	17	......	10	2.1	19
15	......	9	11	13	16	18	21	24	10	2.1	22
16	......	11	13	15	18	21	24	27	11	2.2	32
17	......	13	15	18	21	24	27	31	11	2.2	19
18	......	14	17	21	24	27	31	35	12	2.2	28
19	......	16	20	23	27	30	34	39	13	2.3	23
20	......	18	23	27	30	34	38	43	13	2.3	22
21	......	......	26	30	34	38	42	47	14	2.4	16
22	......	......	30	34	38	42	47	51	14	2.4	21
23	......	......	34	38	42	47	51	56	15	2.4	18
24	......	......	39	43	47	52	57	61	16	2.5	15
25	......	......	43	48	52	57	62	67	16	2.5	9
26	......	......	48	52	57	63	67	73	17	2.6	6
27	......	......	......	57	63	68	73	79	18	2.6	6
28	......	......	......	63	68	74	79	85	18	2.7	6
29	......	......	......	68	74	80	86	92	19	2.8	4
30	......	......	......	73	79	86	92	99	20	2.9	3
31	......	......	......	78	85	92	98	106	20	2.9	3
32	......	......	......	84	91	97	104	113	21	3.0	1
											360

[1] Grafton County.

Logs scaled as cut, 8 to 16 feet long, by the Scribner Decimal C rule. Utilization as close as form of tree allowed.

TABLE 24.—*Sugar maple in Pennsylvania,*[1] *volumes in board feet.*

Diameter, breast-high.	Number of 16-foot logs. 2½	3	3½	4	Diameter, inside bark of top.	Basis.
	Volume—board feet.					
Inches.					*Inches.*	*Trees.*
10	63	90	....	....	6	4
11	74	100	....	....	7	3
12	86	120	....	....	7	2
13	99	130	....	....	8	2
14	110	150	210	....	8	2
15	130	170	230	....	8	2
16	150	190	260	320	9	4
17	....	220	290	360	10	7
18	....	250	330	410	10	5
19	....	280	370	460	11	1
20	....	320	410	510	11	3
21	....	360	460	570	12	2
22	....	400	510	640	13	....
23	....	440	560	710	13	....
24	....	480	620	780	14	1
25	....	530	680	850	15	....
26	....	580	740	920	15	....
27	....	630	810	1,000	16	2
28	....	680	880	1,070	16	1
						41

[1] McKean County.

Height of stump, 1.8 to 3.2 feet. Logs scaled by the Scribner Decimal C rule.

TABLE 25.—*Sugar maple in the Lake States,*[1] *volumes in board feet.*

AVERAGE TOP DIAMETERS.

Diameter, breast-high.	Number of 16-foot logs.						Diameter, inside bark of top.	Basis.
	1½	2	2½	3	3½	4		
	Volume—board feet.							
Inches.							*Inches.*	*Trees.*
8	25	31	38	....	....	....	6	21
9	30	40	50	....	....	....	6	35
10	37	47	62	76	94	....	6	23
11	43	59	76	93	110	....	6	26
12	50	70	91	110	140	170	7	25
13	57	82	110	130	160	190	7	20
14	65	95	130	160	190	220	7	22
15	73	110	150	180	220	250	8	16
16	83	120	170	210	250	290	8	22
17	93	140	190	240	280	330	9	7
18	100	160	220	270	320	380	9	13
19	....	180	240	300	370	430	10	6
20	....	200	270	340	410	490	10	9
21	....	220	300	380	460	550	11	7
22	....	250	340	420	520	620	12	7
23	....	280	370	470	580	690	12	6
24	....	310	410	520	640	770	13	2
25	....	340	460	570	710	840	14	6
26	....	370	500	630	780	930	15	1
27	....	....	550	690	860	1,020	15	2
28	....	....	600	760	940	1,110	16	....
29	....	....	650	820	1,020	1,210	17	....
30	....	....	690	890	1,110	1,300	17	2
								278

[1] Gogebic and Wexford Counties, Mich.; Marinette and Vilas Counties, Wis.

Scaled from taper curves by Scribner Decimal C rule; mostly in 16.3-foot logs, with a few shorter logs where necessary. Stump height, 1 foot. Average utilization.

TABLE 26.—*Sugar maple in the Lake States,*[1] *volumes in board feet.*

MINIMUM TOP DIAMETERS.

Diameter, breast-high.	Number of 16-foot logs.							Diameter, inside bark of top.	Basis.
	2	2½	3	3½	4	4½	5		
	Volume—board feet.								
Inches.								*Inches.*	*Trees.*
8	28	38	48	....	....	....	....	6	21
9	36	49	60	....	....	....	....	6	35
10	44	60	74	....	....	....	....	6	23
11	53	73	89	....	....	....	....	6	26
12	63	86	100	120	150	....	....	6	25
13	74	100	120	140	170	....	....	6	20
14	86	110	140	160	190	220	260	6	22
15	98	130	160	190	210	250	290	6	16
16	110	140	180	210	240	280	330	6	22
17	120	160	200	240	270	320	370	6	7
18	140	180	220	260	300	360	420	6	13
19	....	....	240	290	340	400	470	6	6
20	....	....	270	320	380	450	520	6	9
21	....	....	290	360	430	500	590	7	7
22	....	....	320	390	480	560	660	7	7
23	....	....	360	440	530	630	730	8	6
24	....	....	390	480	590	700	820	8	2
25	....	....	430	530	650	770	910	9	6
26	....	....	480	590	720	860	1,000	10	1
27	....	....	530	650	800	950	1,120	10	2
28	....	....	590	720	890	1,050	1,230	11	....
29	....	....	650	810	980	1,160	1,360	12	....
30	....	....	720	900	1,080	1,280	1,500	13	2
									278

[1] Gogebic and Wexford Counties, Mich.; Marinette and Vilas Counties, Wis.

Scaled from taper curves by the Scribner Decimal C rule; mostly in 16.3-foot logs, with a few shorter logs where necessary. Stump height, 1 foot. Close utilization.

TABLE 27.—*Sugar maple in the Lake States,*[1] *volumes in board feet.*

MAXIMUM TOP DIAMETERS.

Diameter, breast-high.	Number of 16-foot logs.				Diameter, inside bark of top.	Basis.
	1	1½	2	2½		
	Volume—board feet.					
Inches.					*Inches.*	*Trees.*
8	18	50	....	....	7	21
9	24	57	....	....	7	35
10	30	65	....	....	8	23
11	37	73	....	....	8	26
12	44	84	110	130	9	25
13	51	95	120	150	10	20
14	59	110	140	170	10	22
15	68	120	160	190	11	16
16	77	130	180	220	12	22
17	88	150	210	250	12	7
18	99	170	230	290	13	13
19	110	190	260	320	14	6
20	130	210	290	370	14	9
21	140	230	330	410	15	7
22	160	260	360	460	16	7
23	180	290	410	510	17	6
24	200	320	450	560	17	2
25	220	360	500	620	18	6
26	240	400	540	680	19	1
27	270	440	590	740	19	2
28	300	480	640	800	20	....
29	330	520	690	850	21	....
30	360	570	740	910	22	2
						278

[1] Gogebic and Wexford Counties, Mich.; Marinette and Vilas Counties, Wis.

Scaled from taper curves by the Scribner Decimal C rule; mostly in 16.3-foot logs, with a few shorter logs where necessary. Stump height, 1 foot. Poor utilization.

TABLE 28.—*Basswood in the Lake States,*[1] *volumes in board feet.*

AVERAGE TOP DIAMETERS.

Diameter. breast-high.	Number of 16-foot logs. 2	2½	3	3½	4	4½	Diameter inside bark of top.	Basis.
	Volume—board feet.							
Inches.							*Inches.*	*Trees.*
8	30	47	60	....	....	....	6	6
9	36	53	69	....	....	....	6	9
10	44	60	79	100	130	....	6	7
11	53	70	90	110	140	....	6	8
12	63	80	100	130	160	....	7	7
13	75	94	120	150	180	220	7	9
14	89	110	140	170	200	240	7	7
15	100	130	160	190	230	270	8	17
16	120	150	180	220	260	300	8	17
17	....	170	210	250	290	340	9	20
18	....	190	240	280	330	380	9	18
19	....	210	270	320	370	430	10	14
20	....	240	300	360	420	480	10	31
21	....	270	340	400	470	540	11	21
22	....	300	380	450	520	600	12	14
23	....	340	420	500	580	670	12	17
24	....	380	470	560	650	750	13	19
25	....	410	520	620	720	830	14	14
26	....	450	570	680	790	920	15	17
27	....	500	620	750	870	1,010	15	8
28	....	540	680	820	960	1,100	16	9
29	....	590	740	890	1,040	1,190	17	6
30	....	640	800	970	1,130	1,290	17	4
31	....	690	870	1,050	1,220	1,400	18	8
32	....	750	940	1,130	1,310	1,500	18	3
33	....	810	1,010	1,210	1,410	1,610	19	3
34	....	870	1,080	1,290	1,500	1,720	20	4
35	....	940	1,150	1,380	1,600	1,830	20	1
36	....	1,010	1,240	1,470	1,700	1,950	21	....
37	....	1,080	1,320	1,560	1,800	2,060	22	1
38	....	1,150	1,410	1,650	1,900	2,180	22	....
39	....	1,220	1,490	1,750	2,000	2,300	23	....
40	....	1,300	1,570	1,850	2,100	2,420	24	....
								319

[1] Charlevoix and Kalkaska Counties, Mich.; Iron and Price Counties, Wis.

Height of stump, 1 foot, scaled from taper curves, by the Scribner Decimal C rule; mostly in 16.3-foot logs, with a few shorter logs where necessary. Average utilization.

TABLE 29.—*Basswood in the Lake States,*[1] *volumes in board feet.*

MINIMUM TOP DIAMETERS.

Diameter, breast-high.	Number of 16-foot logs.										Diameter inside bark of top.	Basis.
	1½	2	2½	3	3½	4	4½	5	5½	6		
	Volume—board feet.											
Inches.											*Inches.*	*Trees.*
8	16	24	......	......	......	......	......	......	......	......	6	6
9	18	28	46	......	......	......	......	......	......	......	6	9
10	23	34	52	67	86	......	......	......	......	......	6	7
11	29	42	61	78	97	120	......	......	......	......	6	8
12	38	52	73	91	110	140	170	190	......	......	6	7
13	49	66	87	110	130	160	190	210	......	......	6	9
14	63	82	100	120	150	180	210	240	260	......	6	7
15	80	100	120	140	170	200	230	260	290	......	6	17
16	100	120	140	160	190	220	250	290	320	350	6	17
17	......	......	160	180	210	250	280	320	350	390	6	20
18	......	......	180	200	240	280	310	360	390	440	6	18
19	......	......	......	230	270	310	350	400	440	490	6	14
20	......	......	......	250	310	350	390	440	490	540	6	31
21	......	......	......	......	340	390	430	490	550	610	7	21
22	......	......	......	......	380	430	480	540	610	680	7	14
23	......	......	......	......	430	480	530	610	680	760	8	17
24	......	......	......	......	470	530	590	680	760	850	8	19
25	......	......	......	......	520	580	660	750	850	950	9	14
26	......	......	......	......	570	640	720	820	940	1,050	10	17
27	......	......	......	......	620	700	790	900	1,030	1,160	10	8
28	......	......	......	......	670	760	870	990	1,130	1,270	11	9
29	......	......	......	......	730	830	950	1,080	1,240	1,390	12	6
30	......	......	......	......	780	900	1,030	1,180	1,340	1,510	12	4
31	......	......	......	......	840	970	1,120	1,280	1,460	1,640	13	8
32	......	......	......	......	910	1,040	1,210	1,390	1,580	1,770	13	3
33	......	......	......	......	970	1,120	1,300	1,500	1,700	1,900	14	3
34	......	......	......	......	1,040	1,200	1,400	1,610	1,830	2,040	14	4
35	......	......	......	......	1,110	1,290	1,500	1,730	1,960	2,190	15	1
36	......	......	......	......	1,180	1,370	1,610	1,850	2,090	2,340	16	......
37	......	......	......	......	1,260	1,460	1,710	1,980	2,230	2,490	16	1
38	......	......	......	......	1,340	1,560	1,830	2,110	2,380	2,640	17	......
39	......	......	......	......	1,420	1,660	1,940	2,230	2,530	2,800	17	......
40	......	......	......	......	1,500	1,760	2,060	2,360	2,680	2,950	18	......
												319

[1] Charlevoix and Kalkaska Counties, Mich.; Iron and Price Counties, Wis.

Height of stump, 1 foot, scaled from taper curves, by the Scribner Decimal C rule; mostly in 16.3-foot logs, with a few shorter logs where necessary. Close utilization.

TABLE 30.—*Basswood in the Lake States,*[1] *volumes in board feet.*

MAXIMUM TOP DIAMETERS.

Diameter, breast-high.	Number of 16-foot logs. ½	1	1½	2	Diameter inside bark of top.	Basis.
	Volume—board feet.					
Inches.					*Inches.*	*Trees.*
8	7	17	....	....	7	6
9	10	23	....	....	7	9
10	14	28	....	....	8	7
11	17	35	....	....	8	8
12	21	43	74	100	9	7
13	26	51	85	120	10	9
14	31	61	97	140	10	7
15	....	73	110	150	11	17
16	....	86	130	170	12	17
17	....	100	150	190	12	20
18	....	120	170	220	13	18
19	....	130	190	240	14	14
20	....	150	210	270	14	31
21	....	170	240	300	15	21
22	....	190	260	340	16	14
23	....	210	290	380	17	17
24	....	230	330	420	17	19
25	....	250	360	470	18	14
26	....	270	390	520	19	17
27	....	290	430	570	19	8
28	....	320	470	620	20	9
29	....	340	500	670	21	6
30	....	370	540	720	22	4
31	....	390	580	770	22	8
32	....	420	620	830	23	3
33	....	450	660	880	24	3
34	....	480	710	940	24	4
35	....	510	750	1,000	25	1
36	....	540	800	1,060	26	....
37	....	570	840	1,120	26	1
38	....	600	890	1,180	27	....
39	....	630	940	1,240	28	....
40	....	670	990	1,310	28	....
						319

[1] Charlevoix and Kalkaska Counties, Mich.; Iron and Price Counties, Wis.

Height of stump, 1 foot, scaled from taper curves by the Scribner Decimal C rule; mostly in 16.3-foot logs, with a few shorter logs where necessary. Poor utilization.

CUBIC-FOOT VOLUMES.

These tables give the average volumes in cubic feet of forest-grown yellow birch, beech, sugar maple, and basswood trees of different sizes. They are based on stem and branch taper measurements of the trees from which the preceding board-foot tables were made. The volumes are shown separately for "logs" and "topwood." The cubic-foot volume of "logs" includes the stem of the tree between the same stump heights and top diameters as for the board-foot tables, except that for the Lake States tables only the "average" top diameters were used. The volume of "top" is for the portion of the main stem above the upper diameter given, plus the solid volume of all branches suitable for cordwood to a minimum diameter of about 2 inches outside bark at the middle of a 5-foot stick, except for basswood, the branches of which were measured to a minimum middle diameter of 4 inches.

The tables for the Lake States also give the per cent of bark based on the cubic volume of the stem with bark. For basswood and beech the per cent of bark varied consistently with breasthigh diameter; for birch and maple there was no consistent variation.

Table 37 gives the cubic volume of red maple on the Harvard Forest, Petersham, Mass.

TABLE 31.—*Yellow birch in the Lake States,*[1] *volumes in cubic feet.*

Diameter, breasthigh.	Total height of tree—feet.												Diameter, inside bark of top.	Basis, trees.	
	40		50		60		70		80		90				
	Volume [2] including bark—cubic feet.														
	Logs.	Top.	Logs.	Top.	Logs.	Top.	Logs.	Top.	Logs.	Top.	Logs.	Top.		Logs.	Top.
In.													*In.*		
4	......	0.8	......	0.9	......		......	......	......	......	......	......	......	......	......
5	......	1.1	......	1.3	......	1.4	......	......	......	......	......	......	......	......	6
6	......	1.4	1.0	1.6	1.1	1.8	1.2	2.0	......	......	......	......	......	4	4
7	......	1.7	4.5	1.9	4.8	2.0	5.1	2.3	5.4	2.3	......	......	......	12	12
8	......	1.9	7.5	2.1	7.9	2.3	8.5	2.6	9.2	2.6	10.1	2.6	6	11	11
9	......	......	9.9	2.4	10.5	2.6	11.6	2.9	12.8	2.9	14.3	2.9	6	17	17
10	......	......	12.6	2.7	13.4	3.0	15.1	3.2	16.8	3.2	18.7	3.2	6	26	26
11	......	......	15.6	3.1	16.6	3.4	18.9	3.7	21.0	3.7	24.0	3.7	6	17	17
12	......	......	18.6	3.6	20.0	4.0	23.0	4.2	26.0	4.2	29.0	4.2	7	27	27
13	......	......	22.0	4.3	24.0	4.7	28.0	4.9	31.0	4.9	34.0	4.9	7	20	20
14	......	......	25.0	5.1	28.0	5.5	32.0	5.9	36.0	5.9	40.0	5.9	7	16	17
15	......	......	......	......	33.0	6.6	38.0	7.1	42.0	7.1	46.0	7.1	8	8	8
16	......	......	......	......	38.0	8.0	43.0	8.4	48.0	8.4	52.0	8.4	8	16	14
17	......	......	......	......	44.0	9.6	49.0	9.9	54.0	9.9	58.0	9.9	9	15	15
18	......	......	......	......	50.0	11.3	56.0	11.5	61.0	11.5	65.0	11.5	9	15	15
19	......	......	......	......	56.0	13.2	62.0	13.3	67.0	13.3	72.0	13.3	10	13	12
20	......	......	......	......	63.0	15.2	69.0	15.2	74.0	15.2	79.0	15.2	10	9	7
21	......	......	......	......	......	......	75.0	17.2	81.0	17.2	87.0	17.2	11	6	5
22	......	......	......	......	......	......	82.0	19.6	88.0	19.6	95.0	19.6	12	3	2
23	......	......	......	......	......	......	88.0	22.0	96.0	22.0	103.0	22.0	12	5	5
24	......	......	......	......	......	......	95.0	25.0	103.0	25.0	111.0	25.0	13	4	4
25	......	......	......	......	......	......	102.0	29.0	111.0	29.0	120.0	29.0	14	4	4
26	......	......	......	......	......	......	109.0	32.0	119.0	32.0	129.0	32.0	15	2	2
27	......	......	......	......	......	......	116.0	36.0	127.0	36.0	138.0	36.0	15	......	......
28	......	......	......	......	......	......	124.0	40.0	135.0	40.0	147.0	40.0	16	1	1
29	......	......	......	......	......	......	131.0	44.0	144.0	44.0	156.0	44.0	17	2	2
30	......	......	......	......	......	......	138.0	48.0	152.0	48.0	165.0	48.0	17	......	......
														253	253

[1] Gogebic and Wexford Counties, Mich.; Marinette and Vilas Counties, Wis.

[2] The "log" volume is the solid contents of wood and bark between a stump height of 1 foot and the "diameter inside bark of top" shown in the 14th column. The volume of "top" is that contained in the stem above this point, and in addition all branches suitable for cordwood having a diameter, outside bark, of 2 inches or more at the middle of a 5-foot stick. The entire volume of trees too small to yield a 6-inch log is considered topwood. Bark comprises about 13 per cent of the total volume; there was no consistent variation with the size of the tree.

TABLE 32.—*Beech in Michigan,*[1] *volumes in cubic feet.*

Diameter, breast-high.	Height of tree—feet. Volume [2] including bark—cubic feet. 40		50		60		70		80		90		100		Diameter, inside bark of top.	Per cent of bark.	Basis, trees.	
	Logs.	Top.	Logs.	Top.	Logs.	Top.	Logs.	Top.	Logs.	Top.	Logs.	Top.	Logs.	Top.			Logs.	To
In.															*In.*			
4	....	0.7	....	0.9	....	....	....	....	....	....	....	....	....	....	6	8.1	....	3
5	....	.9	....	1.1	....	1.4	....	....	....	....	....	....	....	....	6	8.0	....	3
6	1.0	1.0	1.3	1.3	1.7	1.6	2.4	1.9	....	....	....	....	....	....	6	7.9	2	5
7	2.9	1.3	3.5	1.6	4.7	1.9	6.2	2.2	....	....	....	....	....	....	6	7.8	14	16
8	4.9	1.5	5.9	1.8	7.4	2.2	9.6	2.5	10.4	2.8	12.4	3.1	....	....	6	7.7	20	15
9	7.1	1.7	8.2	2.1	10.0	2.4	12.3	2.8	13.9	3.2	16.5	3.5	....	....	6	7.6	11	15
10	9.4	1.9	10.7	2.3	12.7	2.7	15.4	3.1	17.8	3.5	21.0	3.9	24	4.3	6	7.6	23	23
11	11.8	2.2	13.4	2.6	15.3	3.0	18.8	3.5	22.0	3.9	26.0	4.3	29	4.7	6	7.5	22	29
12	14.4	2.4	16.3	2.9	18.1	3.4	23.0	3.8	27.0	4.3	31.0	4.8	35	5.2	7	7.4	30	25
13	....	....	19.3	3.2	21.0	3.7	27.0	4.2	32.0	4.8	36.0	5.3	41	5.8	7	7.3	19	18
14	....	....	22.0	3.5	24.0	4.1	31.0	4.7	37.0	5.3	42.0	5.9	48	6.5	7	7.2	25	25
15	....	....	25.0	3.9	27.0	4.5	35.0	5.2	43.0	5.9	49.0	6.6	54	7.3	8	7.1	26	23
16	....	....	27.0	4.3	30.0	4.9	40.0	5.6	49.0	6.5	56.0	7.5	62	8.5	8	7.0	28	21
17	....	....	....	....	34.0	5.4	45.0	6.3	55.0	7.3	63.0	8.5	70	9.7	9	6.9	14	14
18	....	....	....	....	37.0	5.9	51.0	7.0	62.0	8.3	71.0	9.6	78	11.0	9	6.8	14	10
19	....	....	....	....	....	....	56.0	8.1	69.0	9.6	79.0	11.1	87	12.6	10	6.7	9	6
20	....	....	....	....	....	....	62.0	9.5	76.0	11.2	87.0	13.0	96	14.8	10	6.6	6	5
21	....	....	....	....	....	....	69.0	11.6	84.0	13.5	96.0	15.4	105	17.3	11	6.5	7	8
22	....	....	....	....	....	....	75.0	14.8	92.0	16.6	104.0	18.3	115	20.0	12	6.4	8	4
23	....	....	....	....	....	....	81.0	18.1	100.0	20.0	113.0	21.7	125	23.0	12	6.3	4	1
24	....	....	....	....	....	....	....	....	....	....	123.0	25.0	135	27.0	13	6.2	3	....
25	....	....	....	....	....	....	....	....	....	....	132.0	29.0	145	31.0	14	6.1	1	....
26	....	....	....	....	....	....	....	....	....	....	142.0	33.0	156	35.0	15	6.0	....	....
																	286	239

[1] Wexford County.

[2] The "log" volume is the solid contents of wood and bark between a stump height of 1 foot and the "diameter inside bark of top" shown in the sixteenth column. The volume of "top" is that contained in the stem above this point, and in addition all branches suitable for cordwood, having a diameter, outside bark, of 2 inches or more at the middle of a 5-foot stick. The entire volume of trees too small to yield a 6-inch log is considered topwood.

TABLE 33.—*Beech in Pennsylvania,*[1] *volumes in cubic feet.*

Diameter, breast-high.	Total height of tree—feet. Volume [2] of logs including bark—cubic feet. 70	80	90	100	110	Volume of top wood.	Diameter, inside bark of top.	Basis.
Inches.						*Cu. ft.*	*Inches.*	*Trees.*
8	8.8	10.1	11.3	....	....	2.8	6	2
9	11.4	13.0	14.6	....	....	3.3	6	6
10	14.3	16.4	18.4	20	....	4.1	6	8
11	17.7	20.0	23.0	25	....	5.0	7	6
12	21.0	24.0	28.0	31	34	5.9	7	6
13	26.0	29.0	33.0	37	40	7.1	7	8
14	30.0	34.0	39.0	43	47	8.8	8	11
15	35.0	40.0	45.0	50	55	10.9	8	5
16	....	46.0	52.0	57	63	13.4	9	13
17	....	52.0	58.0	65	71	16.4	9	10
18	....	58.0	65.0	72	80	19.8	10	10
19	....	64.0	72.0	80	88	23.5	11	11
20	....	70.0	79.0	88	96	27.3	11	5
21	....	....	86.0	95	105	31.1	12	6
22	....	....	92.0	103	113	35.0	13	2
23	....	....	99.0	110	122	39.0	14	5
24	....	....	106.0	118	130	43.0	15	2
25	....	....	113.0	125	138	47.0	16	1
26	....	....	....	133	146	51.0	17	1
27	....	....	....	141	155	55.0	18	....
28	....	....	....	149	164	59.0	19	....
29	....	....	....	157	173	63.0	20	1
30	....	....	....	164	181	68.0	21	1
								120

[1] McKean County.

[2] The "lcg" volume is the solid contents of wood and bark between an average stump height of 2.4 feet and the "diameter inside bark of top" shown in the eighth column. The volume of "top" is that contained in the stem above this point, and in addition all branches suitable for cordwood having a diameter, outside bark, of 2 inches or more at the middle of a 50-inch stick.

TABLE 34.—*Sugar maple in Pennsylvania,*[1] *volumes in cubic feet.*

Diameter, breast-high.	Total height of tree—feet.					Volume of top wood.	Diameter, inside bark of top.	Basis.
	70	80	90	100	110			
	Volume [2] of logs including bark—cubic feet.							
Inches.						*Cu. ft.*	*Inches.*	*Trees.*
10	13.6	15.6	17.5	19.5	....	5.3	6	4
11	16.7	19.1	21.0	24.0	....	5.4	7	3
12	20.0	23.0	26.0	29.0	32	5.5	7	2
13	24.0	27.0	31.0	34.0	37	6.1	8	2
14	28.0	32.0	36.0	40.0	44	7.2	8	2
15	32.0	37.0	42.0	46.0	51	9.0	8	2
16	....	43.0	48.0	53.0	59	11.8	9	4
17	....	49.0	55.0	61.0	67	15.5	10	7
18	....	55.0	62.0	69.0	76	20.0	10	5
19	....	62.0	70.0	78.0	85	24.7	11	1
20	....	69.0	78.0	87.0	95	29.0	11	3
21	....	....	89.0	96.0	106	32.4	12	2
22	....	....	96.0	106.0	117	35.3	13	....
23	....	....	104.0	116.0	128	37.6	13	....
24	....	....	113.0	126.0	139	39.6	14	1
25	....	....	122.0	136.0	149	41.1	15	....
26	....	....	....	145.0	160	42.5	15	....
27	....	....	....	155.0	171	43.9	16	2
28	....	....	....	164.0	181	45.1	16	1
								41

[1] McKean County.

[2] The "log" volume is the solid contents of wood and bark between an average stump height of 2.4 feet and the "diameter inside bark of top" shown in the eighth column. The volume of "top" is that contained in the stem above this point, and in addition all branches suitable for cordwood, having a diameter, outside bark, of 2 inches or more at the middle of a 50-inch stick.

TABLE 35.—*Sugar maple in the Lake States,*[1] *volumes in cubic feet.*

Diameter, breast-high.	Total height of tree—feet.												Diameter inside bark of top.	Basis, trees.	
	50		60		70		80		90		100				
	Volume [2] including bark—cubic feet.														
	Logs.	Top.	Logs.	Top.	Logs.	Top.	Logs.	Top.	Logs.	Top.	Logs.	Top.		Logs.	Top.
Inches.													*Inches.*		
6	0.6	1.8	0.7	2.2	0.8	2.6	1.0	3.0	......	......	......	......	....	9	10
7	3.4	1.9	4.2	2.3	5.0	2.7	5.7	3.2	......	......	......	......	....	18	17
8	6.5	2.0	7.4	2.5	8.4	2.9	9.4	3.3	......	......	......	......	6	21	22
9	9.8	2.2	10.4	2.7	11.6	3.0	13.1	3.5	......	......	......	......	6	35	34
10	13.1	2.4	13.8	2.9	15.2	3.3	17.2	3.7	19.4	4.2	......	......	6	23	24
11	16.7	2.6	17.4	3.1	19.3	3.5	22.0	4.0	25.0	4.5	......	......	6	26	26
12	21.0	2.8	21.0	3.4	24.0	3.8	27.0	4.4	30.0	4.9	34	5.4	7	25	25
13	......	......	26.0	3.7	28.0	4.2	32.0	4.8	36.0	5.4	41	6.0	7	20	20
14	......	......	30.0	4.1	33.0	4.8	37.0	5.4	42.0	6.0	48	6.7	7	22	22
15	......	......	35.0	4.7	38.0	5.4	43.0	6.1	49.0	6.8	55	7.5	8	16	16
16	......	......	40.0	5.4	43.0	6.3	50.0	7.0	56.0	7.8	64	8.5	8	22	22
17	......	......	......	......	49.0	7.2	56.0	8.0	64.0	8.9	72	9.6	9	7	7
18	......	......	......	......	54.0	8.4	63.0	9.4	72.0	10.2	81	11.0	9	13	13
19	......	......	......	......	60.0	9.8	70.0	11.0	80.0	11.8	89	12.6	10	6	5
20	......	......	......	......	66.0	11.5	77.0	12.7	88.0	13.5	99	14.4	10	9	8
21	......	......	......	......	72.0	13.4	85.0	14.6	97.0	15.5	108	16.5	11	7	6
22	......	......	......	......	79.0	15.6	92.0	16.9	105.0	17.8	118	19.0	12	7	7
23	......	......	......	......	85.0	18.3	100.0	20.0	114.0	21.0	128	22.0	12	6	6
24	......	......	......	......	92.0	21.0	108.0	23.0	124.0	25.0	138	26.0	13	2	2
25	......	......	......	......	......	......	116.0	27.0	133.0	30.0	149	32.0	14	6	6
26	......	......	......	......	......	......	125.0	33.0	142.0	36.0	160	40.0	15	1	1
27	......	......	......	......	......	......	134.0	38.0	152.0	42.0	171	47.0	15	2	......
28	......	......	......	......	......	......	142.0	44.0	163.0	48.0	182	54.0	16	......	......
29	......	......	......	......	......	......	152.0	50.0	173.0	55.0	194	61.0	17	......	......
30	......	......	......	......	......	......	161.0	55.0	184.0	61.0	206	68.0	17	2	......
														305	299

[1] Gogebic and Wexford Counties, Mich.; Marinette and Vilas Counties, Wis.

[2] The "log" volume is the solid contents of wood and bark between a stump height of 1 foot and the "diameter inside bark of top" shown in the fourteenth column. The volume of "top" is that contained in the stem above this point, and in addition all branches suitable for cordwood having a diameter, outside bark, of 2 inches or more at the middle of a 5-foot stick. The entire volume of trees too small to yield a 6-inch log is considered topwood.

Bark comprises about 17 per cent of the total volume; there was no consistent variation with the size of the tree.

TABLE 36.—*Basswood in the Lake States,*[1] *volumes in cubic feet.*

Diameter, breast-high.	Total height of tree—feet. Volume [2] of logs including bark—cubic feet.									Volume of topwood.	Diameter inside bark of top.	Per cent of bark.	Basis, trees.	
	40	50	60	70	80	90	100	110	120				Logs.	Top.
Inches.										*Cu. ft.*	*Inches.*			
8	3.9	5.4	7.0	8.3	9.3					2.2	6	22.1	6	6
9	5.7	8.1	10.3	12.3	13.9					2.4	6	21.7	9	7
10	7.8	10.7	13.5	16.1	18.2	19.8				2.6	6	21.2	7	6
11		13.5	17.1	20.0	23.0	25.0				2.8	6	20.8	8	7
12		16.6	21.0	25.0	28.0	30.0	33			3.2	7	20.5	7	5
13			25.0	30.0	33.0	36.0	39			3.7	7	20.1	9	10
14			30.0	35.0	39.0	43.0	46	49		4.3	7	19.7	7	6
15			34.0	41.0	46.0	49.0	53	56		5.2	8	19.4	17	16
16			40.0	47.0	52.0	56.0	60	64	68	6.2	8	19.1	17	15
17					58.0	63.0	68	72	76	7.5	9	18.8	20	18
18					65.0	70.0	75	80	85	9.0	9	18.6	18	13
19					72.0	78.0	83	89	94	10.9	10	18.3	14	15
20					79.0	85.0	91	97	103	13.1	10	18.0	31	28
21					86.0	92.0	99	106	112	15.6	11	17.8	21	20
22					93.0	100.0	107	114	121	18.6	12	17.5	14	12
23					101.0	108.0	115	122	131	22.0	12	17.3	17	17
24					109.0	116.0	123	131	140	26.0	13	17.1	19	17
25					116.0	124.0	132	140	150	30.0	14	16.9	14	12
26					124.0	132.0	140	149	159	34.0	15	16.7	17	15
27					132.0	140.0	149	159	169	39.0	15	16.5	8	10
28					140.0	149.0	158	168	180	45.0	16	16.3	9	9
29					148.0	158.0	170	179	191	52.0	17	16.1	6	6
30					156.0	167.0	177	189	202	59.0	17	15.9	4	4
31						176.0	187	199	214	67.0	18	15.7	8	8
32						185.0	197	211	226	77.0	18	15.5	3	1
33						195.0	208	222	238	88.0	19	15.4	3	3
34						205.0	219	234	251	98.0	20	15.2	4	4
35						215.0	230	247	265	109.0	20	15.1	1	1
36							242	260	279	121.0	21	14.9		
37							255	274	293	131.0	22	14.7	1	
38							268	288	308	142.0	22	14.6		
39							280	302	323	153.0	23	14.4		
40							294	317	338	163.0	24	14.3		
													319	291

[1] Charlevoix and Kalkaska Counties, Mich., Iron and Price Counties, Wis.
[2] The "log" volume is the solid contents of wood and bark between a stump height of 1 foot and the "diameter inside bark of top" shown in the twelfth column. The volume of "top" is that contained in the stem above this point, and in addition all branches suitable for cordwood having a diameter, outside bark, of 4 inches or more at the middle of a 5-foot stick.

TABLE 37.—*Volume of red maple in cubic feet,*[1] *Harvard Forest, Petersham, Mass., 1910–11.*

[Revised and enlarged in 1915.]

Diameter, breast-high.	Total height of tree—feet. Merchantable volume, including bark—cubic feet.							Basis.
	20	30	40	50	60	70	80	
Inches.								*Trees.*
2	0.25	0.35	0.55					59
3	.60	.71	1.00	1.2				51
4	1.00	1.30	1.65	2.0				36
5		2.15	2.40	3.0	3.6			38
6			3.45	4.3	5.2	6.2		42
7			4.70	5.9	7.1	8.4		25
8			6.05	7.8	9.4	10.8	11.8	39
9			7.65	10.1	12.0	13.5	14.8	28
10				12.7	15.0	16.7	18.2	20
11				15.6	18.5	20.5	22.0	23
12				18.9	22.5	24.8	26.4	10
13				22.6	26.8	29.7	31.4	9
14				26.8	31.6	35.0	36.7	8
15				31.5	37.0	40.7	42.7	3
16				36.6	43.2	47.0	49.7	4
17							58.4	2
								397

[1] See "A Volume Table for Red Maple on the Harvard Forest," by E. E. Carter; Bulletin of the Harvard Forestry Club, Vol. II, 1913, pp. 1–8.

The volumes are for stem and branch wood to a minimum diameter, outside bark, of about 2 inches at the middle of a 4-foot length. The measurements were taken in a wide variety of types, including bottom or swale, pine slope, swamp, and birch and maple coppice. Most of the trees more than 6 inches in diameter breast-high were of seedling origin.

CORDWOOD VOLUMES.

So many factors affect the compactness of piled wood that it is impracticable to include volume tables showing the contents in stacked cords[1] of northern hardwood trees of different sizes. Experiments performed in the course of this study showed that the solid contents per cord varied a great deal more with the amount of branchwood and the straightness of the split and round bodywood sections than with the size of the trees alone. The solid contents per cord averaged about 71 cubic feet, but ranged from less than 60 cubic feet for large, spiral-grained, branchy trees, to over 90 cubic feet for small, well-formed trees with few branches.

For use in average old-growth stands of northern hardwoods the following converting factors will give fairly reliable results when applied to the cubic volumes in the preceding tables: 90 cubic feet per cord for tall, slender, straight trees with few large branches; 60 cubic feet per cord for large, spiral-grained, branchy trees; and 75 cubic feet per cord for trees which fall between these extremes. This is for the closeness of utilization described in the footnotes to Tables 31–37.

Cordwood cut from small trees is apt to lie straighter and pile more compactly than that from large timber. Consequently, cordwood tables are more practicable for small than for large trees. Table 38 gives cordwood volumes for red maple on the Harvard Forest, Petersham Mass.[2] They are based on the cubic-foot volumes for red maple given in Table 37 and on the same number of trees, except for those of the 2-inch class, omitted in these tables. Red maples of good height for their diameters should run about as follows:

Diameter, breast-high.	Number of trees per cord.	Diameter, breast-high.	Number of trees per cord.
Inches.		*Inches.*	
4	50	10	6
6	20	12	4
8	9	14	3

TABLE 38.—*Volume of red maple in standard cords of 128 cubic feet, Harvard Forest Petersham, Mass., 1910–11.*

[Revised and enlarged in 1915.]

Diameter, breast-high.	Total height of tree—feet.						
	20	30	40	50	60	70	80
	Merchantable volume—cords.						
Inches.							
3	0.009	0.011	0.015	0.018	....	....	....
4	.015	.019	.024	.029	....	....	....
5	....	.031	.034	.043	0.051	....	....
6	....	....	.048	.060	.072	0.081	....
7	....	....	.063	.079	.095	.113	....
8	....	....	.078	.101	.122	.140	0.153
9	....	....	.095	.125	.149	.168	.184
10	....	....	....	.151	.179	.199	.217
11	....	....	....	.179	.212	.235	.252
12	....	....	....	.210	.251	.276	.294
13	....	....	....	.246	.292	.324	.343
14	....	....	....	.286	.338	.374	.392
15	....	....	....	.332	.390	.430	.450
16	....	....	....	.383	.451	.491	.565
17	....	....	....	....	....	....	.607

[1] A standard cord is a pile 8 feet long by 4 feet high and 4 feet broad. Contractors usually require about 3 inches additional height to allow for settling. Where wood is intended for distillation a length of 50 inches is commonly specified. This influences the converting factor but little, compared with the other variables.

[2] See "A volume Table for Red Maple on the Harvard Forest," by E. E. Carter; Bulletin of the Harvard Forestry Club, Vol. II, 1913, pp. 1–8.

TABLE 39.—*Per cent of wood in piles of red maple cordwood, based on 9 piles of from 2 to 4 cord feet each, Harvard Forest, Petersham, Mass., 1910–11.*

Diameter, breast-high of trees cut and piled.	Per cent of wood in piles.	Diameter, breast-high of trees cut and piled.	Per cent of wood in piles.	Diameter, breast-high of trees cut and piled.	Per cent of wood in piles.	Diameter, breast-high of trees cut and piled.	Per cent of wood in piles.
Inches.		*Inches.*		*Inches.*		*Inches.*	
3	52.5	7	58.0	11	68.0	15	74.0
4	53.6	8	60.2	12	70.0	16	74.6
5	54.9	9	62.8	13	71.5	17	75.0
6	56.2	10	65.5	14	73.0		

GRADED LOG SCALE TABLES.

Tables 40, 41, 42, are taken, with slight modification in arrangement, from "Graded volume tables for Vermont hardwoods," by Irving W. Bailey and Philip C. Heald, Forestry Quarterly, Volume XII, No. 1, pages 5–23. These give the contents in graded lumber of a large number of logs of yellow birch, hard maple, and beech, from hardwood stands on lower slopes and foothills of the Green Mountains in southern Vermont. The logs were run through a single-action band saw cutting a one-eighth inch kerf, and the lumber from each was graded according to the grading rules of the Northern Hardwood Lumber Association, the results being averaged by a curve. The lumber was mostly 1 inch stock, sawed 1⅛ inches thick to allow for shrinkage. The mill crew were men of average skill, experienced in hardwood mills in other regions.

The merchantable length of the trees was seldom over 32 feet; practically no logs were taken above the first branches. The percentage of 1, 2, and 3 log trees was as follows:

	Birch.	Maple.	Beech.
1-log trees	23	22	37
2-log trees	62	60	58
3-log trees	15	18	5

Nearly one-half of the logs cut were defective or abnormal in some particular.[1] The following defects were noted in regard to their influence in decreasing the volumes of the logs: Butt defects, top defects, crook, sweep, knots, seams, shake, miscellaneous. For yellow birch a comparison was made of the contents of nondefective butt logs, nondefective top logs, and the average of all logs. This showed that the difference in volume due both to defect and position in the tree was negligible for logs under 12 inches in diameter at the small end, while for logs 12 inches and over in diameter it amounted to about 9 per cent of the volume of the sound butt logs. It was less than 6 per cent for logs from 12 to 16 inches in diameter, and a little less than 11 per cent for 21 to 24 inch logs. The difference due to position in the tree between sound normal top and butt logs varied from about 3 per cent of the volume of the 12 to 16 inch butt logs to about 10 per cent of the 21 to 24 inch butt logs.

In the table for yellow birch it will be noted that the 10-foot logs show a greater proportion of the poorer grades than do the longer logs. This is particularly noticeable in the No. 1 common red and the No. 2 common grades, and is due especially to the fact that the majority of the 10-foot logs were top logs and hence knotty and of inferior quality.

While they can be applied with substantial accuracy only to conditions similar to those under which they were made, these tables may perhaps be used in other regions

[1] The percentages of defective logs were: Birch 43 per cent, maple 45 per cent, beech 51 per cent.

by carefully studying and comparing defects, methods of utilization, etc., and applying suitable converting factors. With these precautions graded volume tables can be constructed by combining the graded log tables here given with Tables 43, 44, and 55, which show the average taper of trees measured in the Lake States.

For graded volume tables actually constructed from these tables and for additional information relative to the latter the reader is referred to the article by Messrs. Bailey and Heald.

TABLE 40.—*Yellow birch log scale,*[1] *Windham County, Vt.*

Diameter at small end.	10-foot logs. Grade of lumber.							Diameter at small end.	14-foot logs. Grade of lumber.						
	1sts and 2ds red.	1 C. red.	1sts and 2ds.	1 C.	2 C.	3 C.	Total.		1sts and 2ds red.	1 C. red.	1sts and 2ds.	1 C.	2 C.	3 C.	Total.
	Volume—board feet.								Volume—board feet.						
Inches.								*Inches.*							
7	....	....	....	....	10	10	20	7	......	....	......	5	15	10	30
8	....	....	....	....	10	10	20	8	......	....	......	10	15	15	40
9	....	....	....	....	15	15	30	9	......	....	......	10	15	15	40
10	....	....	....	10	15	15	40	10	......	....	5	15	15	15	50
11	....	....	5	10	20	15	50	11	......	....	10	20	20	20	70
12	....	....	5	15	20	20	60	12	......	5	10	25	20	20	80
13	....	....	10	20	20	20	70	13	5	5	20	25	20	25	100
14	....	5	10	20	20	25	80	14	10	5	25	25	20	25	110
15	5	5	15	20	20	25	90	15	15	5	35	30	20	25	130
16	10	10	20	25	20	25	110	16	15	10	40	35	20	30	150
17	10	15	20	30	20	25	120	17	20	15	50	35	20	30	170
18	15	15	25	30	20	25	130	18	35	15	55	35	20	30	190
19	25	20	30	30	20	25	150	19	45	20	70	35	20	30	220
20	30	20	30	30	20	30	160	20	60	20	75	35	20	30	240
21	35	25	35	30	25	30	180	21	75	25	80	35	25	30	270
22	45	30	40	30	25	30	200	22	90	25	90	30	25	30	290
23	60	30	45	30	25	30	220	23	105	25	95	40	25	30	320
24	70	30	55	35	25	35	250	24	120	25	95	40	25	35	340
	12-foot logs.								16-foot logs.						
7	....	....	....	....	10	10	20	7	......	....	......	5	15	10	30
8	....	....	....	5	10	15	30	8	......	....	......	10	15	15	40
9	....	....	....	10	15	15	40	9	......	....	......	15	20	15	50
10	....	....	5	15	15	15	50	10	......	....	5	15	20	20	60
11	....	....	5	20	15	20	60	11	......	....	10	20	20	20	70
12	....	5	10	20	15	20	70	12	5	5	15	25	20	20	90
13	5	5	15	20	15	20	80	13	5	5	20	30	25	25	110
14	5	5	20	25	15	30	100	14	10	5	35	30	25	25	130
15	10	5	25	25	15	30	110	15	15	10	45	30	25	25	150
16	15	10	30	30	15	30	130	16	25	10	55	35	25	30	180
17	25	10	40	30	15	30	150	17	30	15	60	40	25	30	200
18	30	15	45	30	20	30	170	18	40	15	70	40	25	30	220
19	40	15	50	30	15	30	180	19	55	20	80	40	25	30	250
20	50	15	55	30	20	30	200	20	70	25	90	40	25	30	280
21	60	20	60	30	20	30	220	21	90	25	100	40	25	30	310
22	70	25	65	35	20	35	250	22	110	25	110	40	25	30	340
23	85	30	70	30	20	35	270	23	130	25	115	40	25	35	370
24	90	30	70	35	25	40	290	24	145	25	120	40	25	35	390

Based on mill tally of lumber from 1,530 logs.

TABLE 41.—*Beech log scale,*[1] *Windham County. Vt.*

CURVED.

Diameter at small end.	10-foot logs. Grade of lumber. 1sts and 2ds.	1 C.	2 C.	3 C.	Total.	Diameter at small end.	14-foot logs. Grade of lumber. 1sts and 2ds.	1 C.	2 C.	3 C.	Total.
	Volume—board feet.						Volume—board feet.				
Inches.						*Inches.*					
8	......	......	5	25	30	8	......	......	5	25	30
9	......	......	10	20	30	9	......	5	10	25	40
10	......	10	10	20	40	10	......	10	10	30	50
11	......	10	15	25	50	11	......	20	15	35	70
12	......	15	15	30	60	12	5	20	15	40	80
13	5	20	15	30	70	13	15	25	20	40	100
14	10	25	15	30	80	14	20	30	20	40	110
15	15	25	15	35	90	15	25	35	20	50	130
16	20	30	20	40	110	16	35	40	25	50	150
17	30	35	20	45	130	17	45	45	25	55	170
	12-foot logs.						16-foot logs.				
8	......	......	5	25	30	8	......	......	10	30	40
9	......	5	10	25	40	9	......	10	10	30	50
10	......	10	10	30	50	10	......	10	15	35	60
11	......	15	15	30	60	11	......	20	20	40	80
12	5	15	15	35	70	12	5	25	20	40	90
13	10	20	15	35	80	13	15	30	20	45	110
14	15	25	15	35	90	14	20	35	25	50	130
15	20	30	20	40	110	15	30	40	25	55	150
16	30	35	20	45	130	16	40	45	25	60	170
17	40	40	20	50	150	17	55	55	25	65	200

[1] Based on mill tally of lumber from 631 logs.

TABLE 42.—*Sugar maple log scale,*[1] *Windham County, Vt.*

CURVED.

Diameter at small end.	10-foot logs. Grade of lumber.					Diameter at small end.	14-foot logs. Grade of lumber.				
	1sts and 2ds.	1 C.	2 C.	3 C.	Total.		1sts and 2ds.	1 C.	2 C.	3 C.	Total.
	Volume—board feet.						Volume—board feet.				
Inches.						*Inches.*					
7	......	......	5	15	20	7	......	......	10	20	30
8	......	......	10	20	30	8	......	5	10	25	40
9	......	......	10	20	30	9	......	10	10	20	40
10	......	10	10	20	40	10	......	15	10	25	50
11	5	15	10	20	50	11	5	20	10	25	60
12	5	20	15	20	60	12	10	25	15	30	80
13	10	25	10	25	70	13	15	30	15	30	90
14	15	25	15	25	80	14	25	35	20	30	110
15	25	30	15	30	100	15	35	40	20	35	130
16	35	30	15	30	110	16	50	40	20	40	150
17	50	30	15	35	130	17	60	40	20	40	160
18	60	30	15	35	140	18	80	40	20	40	180
19	75	35	15	35	160	19	100	45	20	45	210
20	90	40	15	35	180	20	120	45	20	45	230
	12-foot logs.						16-foot logs.				
7	......	......	5	15	20	7	......	......	10	20	30
8	......	5	5	20	30	8	......	5	10	25	40
9	......	10	10	20	40	9	......	10	15	25	50
10	......	10	10	20	40	10	......	15	15	30	60
11	5	15	10	20	50	11	5	20	15	30	70
12	10	20	15	25	70	12	10	30	20	30	90
13	15	25	15	25	80	13	20	35	20	35	110
14	20	30	15	25	90	14	30	40	20	40	130
15	30	35	15	30	110	15	45	45	20	40	150
16	45	35	15	35	130	16	60	45	20	45	170
17	60	35	15	40	150	17	75	50	20	45	190
18	70	35	15	40	160	18	90	50	25	45	210
19	85	40	15	40	180	19	100	50	25	45	230
20	100	40	20	40	200	20	140	55	25	50	270

[1] Based on mill tally of lumber from 943 logs.

FORM TABLES.

The following tables give diameters inside bark at different heights for average birch, beech, maple, and basswood trees in Michigan and Wisconsin. Above breast-height, the distance from the ground are in units of 8.15 feet above a 1-foot stump. These units represent the half of a 16.3-foot log. The practical use of these tables is to permit scaling trees of given size in terms of any desired log rule, but they also serve as a basis for comparing the species with regard to form. (See similar tables in Bulletin 152, "The Eastern Hemlock.")

TABLE 43.—*Form of yellow birch in the Lake States.*[1]

Diameter, breast-high.	Height above ground—feet.											Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	
	Diameter inside bark—inches.											
50-FOOT TREES.												
Inches.												*Trees.*
4	4.5	4.1	3.9	3.8	3.4	3.0	2.4	......	......	......	......	....
5	5.8	5.2	4.9	4.7	4.3	3.7	3.1	......	......	......	......	5
6	7.1	6.3	6.0	5.7	5.2	4.7	3.9	......	......	......	......	1
7	8.6	7.5	7.0	6.7	6.1	5.5	4.7	......	......	......	......	2
8	10.1	8.7	8.1	7.6	6.9	6.3	5.5	......	......	......	......	1
9	11.7	9.9	9.1	8.6	7.9	7.2	6.2	......	......	......	......	2
10	13.4	11.1	10.0	9.6	8.7	8.0	7.0	......	......	......	......	....
												11
60-FOOT TREES.												
4	4.8	4.2	3.9	3.6	3.1	2.7	2.4	1.9	1.3	......	......	....
5	6.1	5.3	4.9	4.6	4.2	3.7	3.3	2.6	1.9	......	......	1
6	7.4	6.5	5.9	5.6	5.1	4.6	4.0	3.3	2.3	......	......	2
7	8.8	7.6	6.9	6.6	6.1	5.5	4.8	4.0	2.9	......	......	6
8	10.2	8.7	7.9	7.6	6.9	6.3	5.5	4.6	3.3	......	......	7
9	11.7	9.8	9.0	8.6	7.9	7.2	6.3	5.3	3.9	......	......	6
10	13.0	10.9	9.9	9.5	8.7	7.9	7.0	5.9	4.3	......	......	9
11	14.4	12.0	11.0	10.5	9.5	8.7	7.7	6.5	4.9	......	......	5
12	15.8	13.0	11.9	11.3	10.3	9.3	8.3	7.0	5.3	......	......	3
13	17.2	14.1	12.9	12.3	11.1	10.0	9.0	7.6	5.9	......	......	....
14	18.6	15.3	13.9	13.2	11.8	10.7	9.6	8.2	6.3	......	......	1
												40
70-FOOT TREES.												
6	7.8	6.5	5.9	5.6	5.2	4.8	4.3	3.5	2.7	1.9	1.1	1
7	9.1	7.5	7.0	6.6	6.0	5.5	5.0	4.2	3.3	2.4	1.5	4
8	10.3	8.6	8.0	7.5	7.0	6.3	5.7	4.9	4.0	2.9	1.8	3
9	11.6	9.7	8.9	8.5	7.7	7.1	6.5	5.7	4.6	3.4	2.1	8
10	12.9	10.8	10.0	9.5	8.7	7.9	7.1	6.1	5.2	4.0	2.5	15
11	14.2	11.8	11.0	10.4	9.5	8.7	7.9	7.0	5.9	4.5	2.7	9
12	15.5	12.9	11.9	11.4	10.4	9.5	8.7	7.7	6.5	5.0	3.0	15
13	16.8	14.1	13.1	12.3	11.3	10.3	9.5	8.5	7.2	5.5	3.4	11
14	18.1	15.1	14.0	13.3	12.1	11.1	10.2	9.2	7.9	6.1	3.9	5
15	19.5	16.3	15.1	14.1	13.0	11.8	10.9	9.9	8.5	6.7	4.2	2
16	20.9	17.4	16.1	15.1	13.9	12.6	11.7	10.6	9.2	7.3	4.6	5
17	22.3	18.5	17.1	16.0	14.7	13.4	12.3	11.3	9.9	7.8	4.8	2
18	23.7	19.7	18.0	16.9	15.6	14.3	13.2	12.0	10.5	8.4	5.3	3
19	25.2	20.7	18.9	17.8	16.3	14.9	13.8	12.6	11.2	8.9	5.6	2
20	26.7	21.9	20.0	18.7	17.2	15.7	14.5	13.3	11.8	9.5	6.1	1
21	28.1	23.0	20.9	19.6	18.0	16.3	15.1	13.9	12.5	10.1	6.5	1
22	29.8	24.2	21.8	20.6	18.8	17.1	15.7	14.7	13.1	10.7	6.9	1
23	31.2	25.3	22.8	21.5	19.7	17.8	16.5	15.3	13.8	11.3	7.3	....
24	32.9	26.5	23.7	22.4	20.5	18.5	17.2	16.0	14.5	11.9	7.8	1
25	34.3	27.6	24.7	23.1	21.3	19.3	17.8	16.5	15.1	12.5	8.3	1
26	36.2	29.1	25.9	24.0	22.3	20.2	18.5	17.5	15.9	13.1	8.8	....
												90

[1] Gogebic and Wexford Counties, Mich.; Marinette and Vilas Counties, Wis.

TABLE 43.—*Form of yellow birch in the Lake States*—Continued.

Diameter, breast-high.	Height above ground—feet.													Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	
	Diameter inside bark—inches.													
80-FOOT TREES.														
Inches.														*Trees.*
8	10.3	8.7	8.0	7.6	7.1	6.5	6.1	5.4	4.7	3.7	2.7	1.7	......	......
9	11.7	9.7	9.1	8.6	8.0	7.3	6.9	6.3	5.4	4.3	3.1	2.0	......	1
10	12.9	10.8	10.0	9.5	8.9	8.2	7.6	6.9	6.0	4.8	3.6	2.3	......	2
11	14.3	11.9	11.0	10.4	9.7	8.9	8.3	7.7	6.8	5.4	4.0	2.5	......	3
12	15.6	13.1	12.1	11.3	10.5	9.6	9.1	8.4	7.4	6.0	4.5	2.8	......	9
13	17.0	14.1	13.0	12.3	11.4	10.3	9.7	9.1	8.1	6.6	4.9	3.1	......	9
14	18.4	15.3	14.0	13.2	12.2	11.1	10.4	9.7	8.7	7.3	5.4	3.5	......	10
15	19.7	16.3	15.1	14.1	13.1	11.8	11.2	10.5	9.4	7.9	5.9	3.7	......	6
16	21.1	17.5	16.1	15.1	13.9	12.7	11.9	11.1	10.1	8.4	6.3	4.0	......	11
17	22.5	18.6	17.1	16.0	14.8	13.4	12.6	11.8	10.7	8.9	6.8	4.4	......	413
18	24.0	19.8	18.1	16.9	15.6	14.2	13.3	12.5	11.3	9.6	7.3	4.7	......	12
19	25.4	20.9	19.1	17.8	16.4	14.9	13.9	13.1	11.9	10.1	7.8	5.0	......	9
20	27.0	22.2	20.2	18.8	17.3	15.6	14.7	13.7	12.5	10.7	8.3	5.4	......	5
21	28.5	23.4	21.2	19.7	18.1	16.4	15.3	14.3	13.1	11.3	8.7	5.6	......	2
22	30.2	24.6	22.2	20.6	19.1	17.2	16.0	14.9	13.7	11.8	9.2	6.0	......	1
23	31.8	26.0	23.2	21.5	19.7	17.8	16.6	15.5	14.2	12.3	9.7	6.4	......	2
24	33.5	27.4	24.1	22.4	20.5	18.5	17.3	16.1	14.7	12.9	10.2	6.8	......	1
25	35.3	28.9	25.3	23.3	21.3	19.3	18.0	16.8	15.3	13.4	10.6	7.0	......	2
26	37.0	30.3	26.3	24.2	22.1	20.0	18.7	17.4	15.9	13.8	11.0	7.3	......	1
27	38.7	31.8	27.3	25.1	23.0	20.8	19.3	17.9	16.4	14.3	11.4	7.6	......	......
28	40.5	33.4	28.3	26.0	23.7	21.5	20.0	18.5	17.0	14.8	11.8	7.9	......	......
29	......	34.9	29.3	26.9	24.6	22.3	20.7	19.1	17.5	15.4	12.3	8.1	......	1
30	......	36.6	30.3	27.8	25.3	23.0	21.3	19.7	18.0	15.9	12.7	8.5	......	......
														100
90-FOOT TREES.														
16	20.6	17.7	16.4	15.1	13.9	12.9	12.1	11.3	10.3	9.3	7.9	6.3	4.3	......
17	22.3	18.9	17.4	16.1	14.7	13.5	12.7	11.9	11.0	9.8	8.4	6.6	4.5	......
18	24.0	20.0	18.4	16.9	15.6	14.3	13.4	12.5	11.6	10.4	8.9	7.1	4.8	......
19	25.6	21.3	19.4	17.9	16.3	15.0	14.1	13.2	12.2	11.0	9.4	7.5	5.1	2
20	27.3	22.6	20.5	18.8	17.2	15.7	14.7	13.8	12.8	11.5	9.9	7.8	5.3	3
21	29.0	24.0	21.5	19.8	18.1	16.5	15.5	14.6	13.5	12.1	10.4	8.1	5.5	3
22	30.6	25.3	22.6	20.7	18.9	17.2	16.1	15.2	14.1	12.7	10.9	8.5	5.7	1
23	32.5	26.7	23.6	21.7	19.7	17.9	16.8	15.9	14.8	13.3	11.3	8.9	6.0	3
24	34.2	28.1	24.7	22.7	20.6	18.7	17.5	16.5	15.4	13.9	11.8	9.3	6.3	2
25	36.0	29.6	25.6	23.6	21.4	19.5	18.2	17.2	16.1	14.5	12.3	9.6	6.5	1
26	37.6	31.0	26.6	24.5	22.2	20.3	18.9	17.9	16.8	15.1	12.9	10.1	6.8	1
27	39.6	32.6	27.7	25.5	23.2	21.1	19.6	18.6	17.4	15.7	13.3	10.5	7.1	......
28	41.7	34.2	28.8	26.5	24.0	21.9	20.4	19.3	18.1	16.2	13.8	10.9	7.3	1
29	......	35.9	29.9	27.5	24.9	22.7	21.1	19.9	18.8	16.9	14.3	11.2	7.6	1
30	......	37.5	30.9	28.6	25.8	23.5	21.8	20.7	19.5	17.5	14.9	11.7	7.9	......
														18

TABLE 44.—*Form of beech in Michigan.*[1]

Diameter, breast-high.	Height above ground—feet.									Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	
	Diameter inside bark—inches.									
40-FOOT TREES.										
Inches.										*Trees.*
2	2.5	2.2	2.1	1.9	1.7	1.3	......	......	......	....
3	3.5	3.2	3.1	2.8	2.5	2.0	......	......	......	3
4	4.6	4.1	4.0	3.8	3.4	2.7	......	......	......	3
5	5.7	5.1	4.9	4.7	4.2	3.4	......	......	......	2
6	6.8	6.1	5.8	5.6	5.1	4.2	......	......	......	....
7	7.9	7.1	6.8	6.5	5.9	4.9	......	......	......	....
8	9.0	8.0	7.7	7.4	6.8	5.7	......	......	......	....
										8
50-FOOT TREES.										
4	4.6	4.1	4.0	3.8	3.5	3.0	2.5	1.8	......	....
5	5.9	5.3	5.1	4.8	4.4	3.8	3.1	2.2	......	2
6	7.2	6.4	6.0	5.7	5.3	4.5	3.7	2.7	......	1
7	8.6	7.5	7.0	6.7	6.2	5.3	4.3	3.2	......	5
8	10.0	8.6	8.0	7.7	7.1	6.0	4.9	3.7	......	3
9	11.5	9.7	9.0	8.7	8.0	6.7	5.5	4.1	......	2
10	12.9	10.8	9.9	9.6	8.9	7.4	6.1	4.6	......	1
11	14.3	11.9	10.9	10.5	9.7	8.3	6.8	5.1	......	....
12	15.6	12.9	11.8	11.5	10.6	9.0	7.4	5.5	......	....
										14
60-FOOT TREES.										
4	5.5	4.5	4.2	3.8	3.7	3.3	2.8	2.3	1.7	....
5	6.6	5.6	5.2	4.8	4.6	4.1	3.6	3.0	2.3	....
6	7.7	6.6	6.1	5.7	5.5	4.8	4.3	3.6	2.8	1
7	8.8	7.6	7.1	6.7	6.3	5.6	4.9	4.2	3.2	8
8	10.0	8.6	8.1	7.7	7.1	6.3	5.7	4.8	3.7	12
9	11.2	9.7	9.1	8.6	7.9	7.0	6.3	5.4	4.1	4
10	12.4	10.7	10.0	9.8	8.7	7.7	7.0	5.9	4.5	5
11	13.6	11.8	11.0	10.6	9.4	8.4	7.6	6.4	4.9	3
12	14.9	12.9	12.1	11.5	10.2	9.0	8.2	6.9	5.3	2
13	16.2	13.9	13.0	12.5	11.0	9.7	8.7	7.3	5.6	....
14	17.5	15.0	14.1	13.5	11.7	10.3	9.2	7.7	6.0	....
15	18.6	16.2	15.1	14.4	12.5	10.9	9.8	8.2	6.3	....
16	20.1	17.3	16.1	15.4	13.2	11.5	10.3	8.6	6.5	....
17	21.5	18.4	17.2	16.4	14.0	12.1	10.8	9.0	6.9	....
18	22.9	19.5	18.2	17.3	14.7	12.7	11.3	9.5	7.2	1
										36

[1] Wexford County.

TABLE 44.—*Form of beech in Michigan*—Continued.

Diameter, breast-high.	Height above ground—feet.												Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	
	Diameter, inside bark—inches.												
70-FOOT TREES.													
Inches.													*Trees.*
6	7.7	7.0	6.5	6.0	5.7	5.3	5.1	4.6	3.5	2.0	0.9	......	......
7	8.9	7.9	7.4	6.9	6.4	6.1	5.8	5.2	4.0	2.5	1.2	......	1
8	10.1	8.9	8.3	7.8	7.2	6.7	6.3	5.7	4.5	3.0	1.6	......	2
9	11.3	9.8	9.2	8.7	8.0	7.4	7.0	6.3	5.1	3.6	1.9	......	5
10	12.6	10.9	10.2	9.7	8.8	8.0	7.7	6.9	5.7	4.1	2.2	......	9
11	13.9	11.9	11.2	10.6	9.6	8.8	8.2	7.4	6.3	4.7	2.7	......	10
12	15.3	13.0	12.2	11.6	10.4	9.5	8.9	8.0	6.8	5.3	3.2	......	8
13	16.7	14.0	13.2	12.6	11.3	10.2	9.5	8.6	7.4	5.9	3.6	......	6
14	18.2	15.1	14.2	13.5	12.1	11.0	10.2	9.1	7.9	6.4	4.0	......	6
15	19.6	16.2	15.2	14.4	13.0	11.7	10.9	9.7	8.5	6.8	4.4	......	6
16	21.1	17.3	16.2	15.4	13.8	12.5	11.5	10.3	9.0	7.3	4.8	......	3
17	22.6	18.4	17.2	16.4	14.7	13.3	12.2	11.0	9.6	7.8	5.2	......	2
18	24.1	19.6	18.3	17.4	15.5	14.0	12.9	11.6	10.1	8.3	5.5	......	2
19	25.6	20.8	19.3	18.4	16.5	14.9	13.5	12.2	10.6	8.7	5.8	......	1
20	27.2	22.0	20.4	19.4	17.3	15.6	14.3	12.7	11.1	9.2	6.1	......	......
													61
80-FOOT TREES.													
8	10.4	8.7	8.3	7.7	7.3	6.8	6.5	5.9	5.0	4.1	2.9	1.7	......
9	11.8	9.7	9.3	8.7	8.2	7.6	7.2	6.6	5.7	4.7	3.5	2.0	3
10	13.1	10.8	10.2	9.6	9.0	8.4	7.9	7.3	6.4	5.4	3.9	2.4	6
11	14.6	11.8	11.2	10.6	9.9	9.1	8.7	8.0	7.1	6.0	4.4	2.7	6
12	15.9	12.9	12.2	11.6	10.7	9.9	9.4	8.8	7.8	6.5	4.9	3.1	12
13	17.4	14.0	13.2	12.5	11.6	10.7	10.1	9.4	8.5	7.3	5.5	3.4	8
14	18.8	15.1	14.2	13.4	12.4	11.5	10.8	10.1	9.1	7.8	5.9	3.7	7
15	20.2	16.2	15.2	14.4	13.3	12.2	11.6	10.9	9.9	8.5	6.4	4.1	13
16	21.6	17.4	16.2	15.4	14.1	13.0	12.3	11.6	10.6	9.1	7.0	4.5	9
17	23.0	18.5	17.3	16.3	15.0	13.8	13.1	12.3	11.3	9.8	7.6	4.9	9
18	24.4	19.7	18.3	17.3	15.9	14.6	13.7	13.0	11.9	10.5	8.1	5.3	3
19	25.8	20.8	19.4	18.3	16.8	15.4	14.5	13.7	12.7	11.1	8.7	5.8	2
20	27.2	22.0	20.5	19.2	17.6	16.2	15.2	14.4	13.3	11.7	9.3	6.3	3
21	28.5	23.2	21.6	20.2	18.4	16.9	15.9	15.1	14.0	12.4	9.9	6.6	1
22	29.9	24.4	22.6	21.2	19.2	17.7	16.6	15.7	14.7	13.0	10.4	7.2	......
													82

TABLE 44.—*Form of beech in Michigan*—Continued.

90-FOOT TREES.

Diameter, breast-high.	Height above ground—feet.														Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	
	Diameter inside bark—inches.														
Inches.															*Trees.*
8	12.1	8.7	8.3	7.8	7.4	7.0	6.6	6.2	5.6	4.7	3.8	2.5	1.5	.....	....
9	13.3	9.8	9.3	8.8	8.3	7.8	7.4	6.9	6.4	5.6	4.4	3.1	1.9	.....	....
10	14.5	10.8	10.3	9.7	9.2	8.6	8.1	7.6	7.1	6.3	5.0	3.6	2.3	.....	1
11	15.7	11.8	11.2	10.7	10.0	9.4	8.9	8.4	7.8	6.9	5.6	4.2	2.7	.....	4
12	16.9	13.0	12.3	11.6	10.9	10.2	9.6	9.1	8.5	7.5	6.2	4.7	3.2	.....	6
13	18.1	14.0	13.3	12.6	11.8	11.0	10.4	9.9	9.2	8.2	6.8	5.3	3.6	.....	7
14	19.4	15.2	14.3	13.5	12.6	11.8	11.1	10.6	9.9	8.8	7.4	5.9	4.1	.....	9
15	20.6	16.3	15.3	14.5	13.5	12.7	11.9	11.3	10.6	9.5	8.1	6.5	4.5	.....	8
16	21.9	17.3	16.3	15.4	14.4	13.4	12.7	12.0	11.3	10.1	8.7	7.0	5.0	.....	11
17	23.2	18.5	17.3	16.4	15.3	14.2	13.5	12.8	12.0	10.8	9.3	7.6	5.4	.....	8
18	24.5	19.6	18.4	17.3	16.2	15.0	14.2	13.6	12.7	11.4	10.0	8.2	5.9	.....	6
19	25.7	20.8	19.3	18.3	17.0	15.8	15.0	14.3	13.4	12.1	10.6	8.7	6.3	.....	7
20	26.9	21.9	20.3	19.3	17.9	16.6	15.7	15.0	14.1	12.8	11.2	9.3	6.7	.....	3
21	28.2	23.0	21.4	20.2	18.7	17.3	16.4	15.7	14.8	13.5	11.9	9.9	7.2	.....	3
22	29 5	24.1	22.3	21.2	19.6	18.2	17.1	16.4	15.5	14.1	12.5	10.4	7.6	.....	2
23	30.7	25.2	23.4	22.2	20.5	18.9	17.9	17.1	16.1	14.8	13.2	11.0	8.0	.....	2
24	32.0	26.3	24.3	23.1	21.4	19.7	18.6	17.8	16.8	15.4	13.9	11.6	8.4	.....	....
25	33.3	27.4	25.4	24.1	22.3	20.5	19.4	18.5	17.5	16.1	14.5	12.2	8.8	.....	1
26	34.5	28.5	26.3	25.1	23.2	21.3	20.1	19.3	18.2	16.7	15.1	12.7	9.3	.....	....
															78

100-FOOT TREES.

Diameter, breast-high.	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	Basis.
10	15.0	10.7	10.3	9.8	9.4	9.0	8.6	8.2	7.6	6.8	5.8	4.7	3.7	2.7	....
11	16.2	11.8	11.4	10.7	10.2	9.8	9.4	8.9	8.3	7.5	6.4	5.3	4.2	3.0	....
12	17.3	12.9	12.3	11.7	11.0	10.5	10.1	9.6	9.0	8.2	7.1	5.8	4.6	3.3	....
13	18.5	14.0	13.4	12.6	11.9	11.4	10.9	10.4	9.7	8.9	7.7	6.4	5.1	3.6	....
14	19.8	15.1	14.3	13.5	12.7	12.1	11.6	11.1	10.4	9.6	8.3	6.9	5.5	3.9	1
15	21.0	16.2	15.4	14.5	13.6	12.9	12.4	11.9	11.1	10.2	9.0	7.5	5.9	4.2	1
16	22.2	17.3	16.3	15.4	14.5	13.7	13.2	12.6	11.8	10.9	9.6	8.1	6.3	4.5	2
17	23.4	18.5	17.3	16.4	15.3	14.5	14.0	13.4	12.6	11.6	10.3	8.7	6.9	4.8	....
18	24.7	19.7	18.3	17.3	16.1	15.3	14.7	14.1	13.3	12.3	11.0	9.3	7.3	5.1	....
19	25.9	20.8	19.4	18.3	17.0	16.1	15.5	14.9	14.0	13.0	11.6	9.9	7.8	5.5	....
20	27.1	22.0	20.4	19.2	17.9	16.9	16.3	15.7	14.7	13.7	12.3	10.5	8.2	5.8	....
21	28.4	23.2	21.5	20.2	18.8	17.7	17.1	16.4	15.5	14.4	13.0	11.1	8.7	6.2	3
22	29.6	24.4	22.6	21.2	19.6	18.5	17.8	17.2	16.2	15.0	13.6	11.7	9.2	6.5	3
23	30.9	25.6	23.7	22.2	20.5	19.2	18.6	17.9	16.9	15.7	14.3	12.3	9.6	6.8	3
24	32.1	26.8	24.8	23.2	21.4	20.0	19.3	18.7	17.6	16.4	14.9	12.8	10.0	7.1	2
25	33.4	28.1	25.9	24.2	22.4	20.8	20.1	19.4	18.3	17.1	15.7	13.5	10.5	7.4	1
26	34.6	29.4	27.0	25.2	23.3	21.6	20.8	20.2	19.1	17.8	16.2	14.0	11.0	7.7	....
															16

TABLE 45.—*Form of sugar maple in the Lake States.*[1]

Diameter, breast-high.	Height above ground—feet.									Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	
	Diameter inside bark—inches.									
50-FOOT TREES.										
Inches.										*Trees.*
4	4.9	4.3	3.9	3.7	3.4	2.8	2.1	1.3	....	....
5	5.9	5.2	4.8	4.6	4.3	3.7	2.9	2.0	....	1
6	6.8	6.1	5.7	5.4	5.1	4.5	3.6	2.7	....	4
7	7.8	7.0	6.6	6.3	5.9	5.3	4.5	3.5	....	7
8	8.7	7.9	7.4	7.2	6.8	6.1	5.3	4.3	....	1
9	9.7	8.8	8.3	8.0	7.6	6.9	6.1	5.1	....	1
10	10.6	9.7	9.3	8.9	8.5	7.8	7.0	5.9	....	1
11	11.6	10.7	10.1	9.8	9.3	8.6	7.8	6.7	....	....
12	12.5	11.5	11.0	10.6	10.1	9.4	8.7	7.5	....	....
										15
60-FOOT TREES.										
4	4.7	4.2	3.8	3.6	3.4	2.9	2.4	1.8	1.3	....
5	5.7	5.2	4.8	4.5	4.2	3.7	3.2	2.6	1.8	1
6	6.7	6.1	5.7	5.4	5.1	4.6	4.0	3.3	2.3	5
7	7.7	7.0	6.6	6.3	6.0	5.4	4.8	4.0	2.9	11
8	8.7	7.9	7.5	7.2	6.9	6.3	5.6	4.7	3.5	11
9	9.7	8.9	8.4	8.1	7.7	7.1	6.3	5.5	4.0	11
10	10.7	9.8	9.3	9.0	8.6	7.9	7.2	6.1	4.5	3
11	11.8	10.8	10.3	9.9	9.5	8.7	8.0	6.9	5.1	1
12	12.8	11.7	11.1	10.7	10.3	9.6	8.8	7.7	5.7	4
13	13.9	12.7	12.0	11.6	11.1	10.4	9.6	8.5	6.2	1
14	14.9	13.6	12.9	12.5	11.9	11.1	10.4	9.1	6.8	....
15	16.0	14.5	13.8	13.3	12.7	11.9	11.2	9.9	7.4	....
16	16.9	15.4	14.6	14.2	13.6	12.7	12.0	10.7	7.9	....
17	18.0	16.3	15.5	15.1	14.4	13.5	12.8	11.4	8.5	....
18	19.0	17.3	16.4	15.9	15.2	14.3	13.5	12.1	9.0	....
										48

[1] Gogebic and Wexford Counties, Mich.; Marinette and Vilas Counties, Wis.

Table 45.—*Form of sugar maple in the Lake States*—Continued.

70-FOOT TREES.

Diameter, breast-high.	Height above ground—feet.												Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	
	Diameter inside bark—inches.												
Inches.													*Trees.*
6	6.7	6.1	5.7	5.3	5.0	4.6	4.3	3.8	2.9	1.8	0.9	......	....
7	7.7	7.0	6.5	6.3	6.0	5.5	5.1	4.5	3.5	2.3	1.2	......	....
8	8.9	7.9	7.4	7.2	6.9	6.3	5.9	5.2	4.1	2.7	1.5	......	8
9	9.9	8.9	8.3	8.1	7.7	7.1	6.6	5.8	4.6	3.2	1.9	......	18
10	11.1	9.8	9.2	9.0	8.6	8.0	7.4	6.5	5.2	3.7	2.2	......	12
11	12.3	10.8	10.2	9.9	9.5	8.8	8.1	7.2	5.9	4.3	2.6	......	12
12	13.6	11.7	11.2	10.8	10.3	9.6	8.9	7.9	6.5	4.9	3.0	......	14
13	14.7	12.7	12.1	11.7	11.1	10.3	9.5	8.5	7.1	5.5	3.4	......	5
14	16.0	13.7	13.1	12.7	12.0	11.1	10.2	9.1	7.7	6.0	3.8	......	5
15	17.3	14.7	14.1	13.6	12.7	11.8	10.9	9.7	8.2	6.6	4.3	......	5
16	18.8	15.6	15.1	14.5	13.6	12.7	11.6	10.3	8.9	7.2	4.8	......	5
17	20.2	16.7	15.9	15.3	14.4	13.3	12.2	10.9	9.4	7.7	5.0	......	....
18	21.8	17.9	17.0	16.3	15.1	14.1	12.9	11.5	10.0	8.1	5.3	......	1
19	23.4	18.9	17.9	17.1	15.9	14.7	13.5	12.1	10.5	8.7	5.6	......	1
20	24.9	19.8	18.9	18.1	16.8	15.5	14.1	12.7	11.1	9.1	5.9	......	1
21	26.6	20.9	19.9	19.0	17.5	16.1	14.7	13.2	11.6	9.5	6.2	......	1
22	28.3	22.0	21.0	19.9	18.3	16.9	15.4	13.8	12.1	10.1	6.6	......	....
23	30.0	23.1	21.9	20.8	19.0	17.6	16.1	14.4	12.7	10.6	7.0	......	....
24	31.6	24.1	23.0	21.8	19.8	18.2	16.7	15.1	13.3	11.1	7.3	......	....
													88

80-FOOT TREES.

Diameter, breast-high.	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	Basis.
8	8.9	8.0	7.6	7.4	7.0	6.5	6.0	5.5	4.7	3.6	2.5	1.5	1
9	10.1	8.9	8.5	8.3	7.8	7.3	6.9	6.2	5.3	4.4	3.1	1.9	5
10	11.4	9.9	9.5	9.1	8.7	8.0	7.5	6.9	6.1	5.0	3.6	2.1	6
11	12.7	10.9	10.4	10.0	9.5	8.9	8.3	7.6	6.7	5.7	4.0	2.4	13
12	14.1	12.0	11.3	11.0	10.4	9.7	9.0	8.3	7.5	6.3	4.5	2.8	7
13	15.5	13.0	12.4	11.9	11.2	10.5	9.8	9.0	8.1	6.9	5.1	3.1	11
14	16.8	14.0	13.3	12.7	12.1	11.3	10.5	9.7	8.9	7.5	5.5	3.4	14
15	18.2	15.0	14.3	13.7	12.8	12.0	11.2	10.4	9.5	8.2	6.1	3.7	6
16	19.6	16.1	15.3	14.6	13.7	12.8	11.9	11.1	10.2	8.9	6.6	4.0	13
17	21.1	17.1	16.3	15.5	14.5	13.5	12.7	11.7	10.9	9.5	7.1	4.4	5
18	22.5	18.3	17.3	16.4	15.3	14.3	13.4	12.5	11.5	10.1	7.6	4.7	3
19	24.0	19.3	18.3	17.3	16.1	15.0	14.0	13.1	12.2	10.7	8.1	5.0	2
20	25.5	20.5	19.4	18.3	16.8	15.7	14.7	13.7	12.9	11.3	8.7	5.3	3
21	26.9	21.6	20.4	19.2	17.7	16.4	15.3	14.4	13.5	11.9	9.1	5.7	2
22	28.5	22.7	21.4	20.1	18.5	17.1	15.9	15.0	14.1	12.5	9.7	6.0	1
23	30.0	23.9	22.5	21.1	19.3	17.7	16.6	15.7	14.7	13.0	10.2	6.3	....
24	31.5	25.1	23.6	22.1	20.2	18.5	17.2	16.3	15.3	13.6	10.7	6.6	....
25	33.0	26.3	24.7	23.1	21.0	19.1	17.8	16.9	15.9	14.2	11.2	7.0	1
26	34.5	27.5	25.8	24.1	21.8	19.8	18.5	17.5	16.5	14.7	11.8	7.3	....
27	36.1	28.8	26.9	25.1	22.6	20.4	19.1	18.1	17.1	15.3	12.3	7.7	1
28	37.6	29.9	28.0	26.1	23.5	21.2	19.7	18.7	17.7	15.8	12.7	7.9	....
29	39.2	31.3	29.1	27.2	24.3	21.8	20.3	19.4	18.3	16.3	13.3	8.3	....
30	40.6	32.5	30.2	28.2	25.1	22.5	20.9	20.0	19.0	16.9	13.8	8.7	....
													94

TABLE 45.—*Form of sugar maple in the Lake States*—Continued.

Diameter, breast-high.	Height above ground—feet.														Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	
	Diameter inside bark—inches.														
90-FOOT TREES.															
Inches.															*Trees.*
10	11.6	10.0	9.5	9.3	8.8	8.3	7.7	7.1	6.5	5.8	4.7	3.3	1.9	.....	1
11	13.0	11.0	10.5	10.2	9.6	9.0	8.5	7.9	7.3	6.5	5.3	3.7	2.2	.....	......
12	14.5	12.1	11.4	11.1	10.5	9.8	9.2	8.7	8.1	7.2	5.8	4.1	2.5	.....	......
13	15.9	13.2	12.4	11.9	11.2	10.6	10.0	9.4	8.8	7.9	6.4	4.6	2.8	.....	3
14	17.4	14.3	13.4	12.8	12.1	11.4	10.8	10.2	9.6	8.6	7.0	5.1	3.1	.....	3
15	18.8	15.3	14.3	13.7	12.9	12.2	11.5	10.9	10.3	9.2	7.6	5.5	3.4	.....	4
16	20.3	16.5	15.4	14.7	13.7	12.9	12.3	11.7	11.1	9.9	8.2	6.0	3.7	.....	4
17	21.7	17.5	16.5	15.5	14.6	13.5	12.9	12.5	11.8	10.6	8.8	6.4	4.0	.....	2
18	23.1	18.7	17.5	16.5	15.4	14.3	13.6	13.1	12.5	11.3	9.4	6.9	4.3	.....	7
19	24.5	19.7	18.5	17.4	16.3	15.2	14.5	13.8	13.2	11.9	9.9	7.3	4.6	.....	3
20	25.9	20.9	19.5	18.3	17.1	16.0	15.2	14.6	13.9	12.5	10.5	7.8	4.9	.....	2
21	27.3	22.0	20.5	19.2	17.9	16.7	15.9	15.2	14.5	13.1	11.1	8.3	5.2	.....	4
22	28.7	23.1	21.5	20.2	18.8	17.5	16.5	15.9	15.2	13.8	11.6	8.7	5.5	.....	3
23	30.1	24.2	22.5	21.2	19.5	18.2	17.3	16.5	15.8	14.4	12.1	9.1	5.8	.....	3
24	31.5	25.4	23.6	22.1	20.4	19.0	18.0	17.2	16.4	15.0	12.7	9.5	6.1	.....	2
25	32.8	26.5	24.5	23.1	21.3	19.7	18.7	17.7	17.0	15.6	13.1	10.0	6.4	.....	3
26	34.2	27.6	25.6	24.1	22.1	20.5	19.3	18.4	17.6	16.2	13.7	10.4	6.7	.....	1
27	35.5	28.8	26.7	25.1	22.9	21.2	20.1	19.1	18.1	16.8	14.3	10.8	7.0	.....	......
28	37.0	29.9	27.7	26.1	23.7	22.0	20.7	19.7	18.8	17.3	14.9	11.3	7.3	.....	......
29	38.3	31.1	28.7	27.1	24.7	22.7	21.5	20.3	19.3	18.0	15.3	11.7	7.7	.....	......
30	39.7	32.3	29.8	28.2	25.5	23.5	22.1	21.0	20.0	18.6	15.9	12.1	8.0	.....	......
															45
100-FOOT TREES.															
12	15.8	12.5	11.7	11.1	10.5	9.9	9.5	9.1	8.5	7.7	6.7	5.5	4.0	2.7	......
13	17.0	13.5	12.7	11.9	11.3	10.6	10.2	9.8	9.3	8.4	7.4	6.0	4.5	3.0	......
14	18.3	14.5	13.8	12.9	12.2	11.5	11.0	10.6	10.0	9.1	8.0	6.5	4.9	3.3	......
15	19.6	15.7	14.8	13.8	13.0	12.3	11.9	11.4	10.8	9.9	8.7	7.1	5.3	3.6	1
16	21.0	16.8	15.7	14.7	13.9	13.1	12.6	12.2	11.5	10.6	9.3	7.7	5.8	3.9	......
17	22.1	17.9	16.8	15.6	14.7	13.9	13.5	13.0	12.3	11.4	10.0	8.2	6.3	4.2	......
18	23.5	19.0	17.8	16.5	15.6	14.8	14.3	13.7	13.0	12.1	10.6	8.8	6.7	4.4	2
19	24.7	20.1	18.8	17.5	16.4	15.5	15.0	14.5	13.8	12.8	11.3	9.3	7.1	4.8	......
20	26.1	21.1	19.7	18.4	17.3	16.3	15.7	15.1	14.5	13.5	11.9	9.9	7.5	5.1	3
21	27.4	22.1	20.7	19.3	18.1	17.1	16.5	15.9	15.1	14.1	12.5	10.3	7.9	5.4	......
22	28.8	23.2	21.7	20.3	19.0	17.9	17.2	16.5	15.7	14.7	13.0	10.8	8.3	5.7	3
23	30.0	24.3	22.6	21.3	19.8	18.7	17.9	17.1	16.5	15.5	13.7	11.3	8.7	6.0	3
24	31.5	25.4	23.6	22.2	20.7	19.5	18.7	17.9	17.1	16.1	14.3	11.9	9.2	6.2	......
25	32.8	26.4	24.5	23.1	21.5	20.3	19.4	18.5	17.7	16.7	14.8	12.5	9.7	6.5	2
26	34.2	27.5	25.5	24.1	22.4	21.0	20.0	19.1	18.3	17.3	15.5	12.9	10.0	6.7	......
27	35.5	28.6	26.5	25.1	23.2	21.8	20.8	19.8	19.0	17.9	16.1	13.3	10.3	7.1	1
28	36.9	29.7	27.4	26.0	24.0	22.5	21.5	20.5	19.6	18.5	16.6	13.9	10.8	7.3	......
29	38.1	30.7	28.3	27.0	24.8	23.3	22.2	21.1	20.2	19.1	17.3	14.5	11.2	7.5	......
30	39.6	31.8	29.3	27.9	25.7	24.1	22.9	21.7	20.7	19.6	17.9	15.1	11.5	7.7	2
															17

TABLE 46.—*Form of basswood in the Lake States.*[1]

Diameter, breast-high.	Height above ground—feet.							Basis.
	1	2	3	4.5	9.15	17.3	25.45	
	Diameter inside bark—inches.							
30-FOOT TREES.								
Inches.								*Trees.*
2	2.1	2.0	1.9	1.7	1.5	....	....	....
3	3.1	3.0	2.8	2.6	2.3	....	....	2
4	4.1	3.9	3.8	3.5	2.9	....	....	2
5	5.2	4.9	4.6	4.4	3.7	....	....	....
6	6.3	5.9	5.6	5.3	4.4	....	....	1
7	7.5	6.9	6.5	6.2	5.2	....	....	....
8	8.6	7.9	7.4	7.1	5.8	....	....	....
								5
40-FOOT TREES.								
2	2.1	2.0	1.9	1.7	1.5	1.3	....	....
3	3.1	3.0	2.8	2.6	2.3	1.8	....	....
4	4.1	3.9	3.8	3.5	3.1	2.5	....	....
5	5.2	4.9	4.6	4.4	3.9	3.0	....	2
6	6.3	5.9	5.6	5.3	4.7	3.6	....	....
7	7.5	6.9	6.5	6.2	5.5	4.2	....	....
8	8.6	7.9	7.4	7.1	6.2	4.8	....	....
9	9.9	8.9	8.4	8.0	7.1	5.5	....	....
10	11.3	9.9	9.4	9.0	7.9	6.1	....	....
								2
50-FOOT TREES.								
2	2.1	2.0	1.9	1.7	1.6	1.4	1.1	....
3	3.1	3.0	2.8	2.6	2.4	2.1	1.8	....
4	4.1	3.9	3.8	3.5	3.2	2.8	2.4	....
5	5.2	4.9	4.6	4.4	4.0	3.5	3.0	2
6	6.3	5.9	5.6	5.3	4.8	4.2	3.5	2
7	7.5	6.9	6.5	6.2	5.6	4.9	4.1	3
8	8.6	7.9	7.4	7.1	6.5	5.6	4.7	....
9	9.9	8.9	8.4	8.0	7.3	6.3	5.3	....
10	11.3	9.9	9.4	9.0	8.1	7.1	6.0	....
11	12.7	11.0	10.4	10.0	8.9	7.8	6.6	....
12	14.2	12.1	11.4	10.9	9.8	8.5	7.1	....
								7

[1] Charlevoix and Kalkaska Counties, Mich.; Iron and Price Counties, Wis.

TABLE 46.—*Form of basswood in the Lake States*—Continued.

60-FOOT TREES.												
Diameter, breast-high.	Height above ground—feet.											Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	
	Diameter inside bark—inches.											
Inches.												*Trees.*
4	4.1	3.9	3.8	3.5	3.2	3.0	2.7	2.3	1.8	......	......	....
5	5.2	4.9	4.6	4.4	4.1	3.8	3.4	2.9	2.1	......	......	....
6	6.3	5.9	5.6	5.3	4.9	4.5	4.0	3.4	2.6	......	......	....
7	7.5	6.9	6.5	6.2	5.8	5.2	4.8	4.0	3.0	......	......	....
8	8.6	7.9	7.4	7.1	6.6	6.1	5.4	4.6	3.4	......	......	5
9	9.9	8.9	8.4	8.0	7.4	6.8	6.1	5.2	3.9	......	......	4
10	11.3	9.9	9.4	9.0	8.2	7.6	6.8	5.8	4.4	......	......	2
11	12.7	11.0	10.4	10.0	9.2	8.3	7.6	6.5	4.9	......	......	3
12	14.2	12.1	11.4	10.9	10.0	9.1	8.3	7.1	5.4	......	......	1
13	15.8	13.2	12.4	11.8	11.0	9.9	9.0	7.7	5.9	......	......	....
14	17.4	14.4	13.5	12.8	11.8	10.6	9.6	8.3	6.4	......	......	....
15	19.1	15.6	14.5	13.7	12.7	11.4	10.4	9.0	6.9	......	......	1
16	20.8	16.8	15.5	14.7	13.6	12.2	11.1	9.7	7.4	......	......	....
												16
70-FOOT TREES.												
6	6.3	5.9	5.6	5.3	5.1	4.7	4.3	3.8	3.3	2.6	1.8	....
7	7.5	6.9	6.5	6.2	5.9	5.5	5.1	4.5	3.9	3.2	2.2	....
8	8.6	7.9	7.4	7.1	6.7	6.3	5.8	5.2	4.5	3.7	2.5	1
9	9.9	8.9	8.4	8.0	7.5	7.0	6.5	5.8	5.1	4.3	2.9	4
10	11.3	9.9	9.4	9.0	8.4	7.8	7.2	6.5	5.7	4.8	3.3	4
11	12.7	11.0	10.4	10.0	9.2	8.6	7.9	7.1	6.3	5.4	3.6	4
12	14.2	12.1	11.4	10.9	10.0	9.2	8.6	7.8	6.9	5.8	4.0	....
13	15.8	13.2	12.4	11.8	10.9	10.0	9.3	8.5	7.5	6.4	4.4	5
14	17.4	14.4	13.5	12.8	11.7	10.7	9.9	9.1	8.3	7.0	4.8	2
15	19.1	15.6	14.5	13.7	12.5	11.5	10.7	9.8	8.8	7.6	5.1	4
16	20.8	16.8	15.5	14.7	13.3	12.2	11.3	10.4	9.4	8.1	5.5	2
17	22.6	18.1	16.5	15.6	14.0	12.8	12.1	11.0	10.0	8.7	6.0	4
18	24.3	19.4	17.5	16.6	14.9	13.7	12.7	11.7	10.7	9.3	6.4	5
19	26.0	20.8	18.5	17.5	15.7	14.3	13.4	12.3	11.3	9.9	6.8	....
20	27.6	22.0	19.5	18.5	16.5	15.1	14.0	13.0	11.9	10.4	7.3	1
21	29.1	23.3	20.5	19.4	17.3	15.7	14.7	13.6	12.6	11.0	7.7	....
22	30.6	24.5	21.6	20.3	18.0	16.5	15.3	14.4	13.3	11.6	8.2	....
23	32.1	25.7	22.6	21.2	18.8	17.1	16.0	14.9	13.9	12.2	8.6	....
24	33.4	26.8	23.6	22.2	19.5	17.9	16.7	15.6	14.5	12.8	9.2	....
												36

TABLE 46.—*Form of basswood in the Lake States*—Continued.

80-FOOT TREES.														
Diameter, breast-high	Height above ground—feet.													Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	
	Diameter inside bark—inches.													
Inches.														*Trees.*
8	8.6	7.9	7.4	7.1	6.8	6.3	5.9	5.4	4.9	4.3	3.6	2.5	1.1	......
9	9.9	8.9	8.4	8.0	7.6	7.1	6.6	6.1	5.5	4.9	4.1	2.8	1.3	1
10	11.3	9.9	9.4	9.0	8.5	7.9	7.4	6.7	6.1	5.4	4.5	3.2	1.4	1
11	12.7	11.0	10.4	10.0	9.3	8.6	8.1	7.5	6.8	6.1	5.0	3.5	1.6	1
12	14.2	12.1	11.4	10.9	10.2	9.4	8.7	8.1	7.4	6.6	5.5	3.8	1.7	3
13	15.8	13.2	12.4	11.8	11.1	10.1	9.5	8.8	8.1	7.2	5.9	4.2	1.9	1
14	17.4	14.4	13.5	12.8	11.8	10.9	10.2	9.5	8.7	7.8	6.4	4.6	2.1	2
15	19.1	15.6	14.5	13.7	12.7	11.7	11.0	10.2	9.3	8.4	6.9	4.9	2.3	6
16	20.8	16.8	15.5	14.7	13.5	12.3	11.5	10.7	10.0	9.0	7.4	5.3	2.5	7
17	22.6	18.1	16.5	15.6	14.3	13.1	12.3	11.5	10.6	9.6	7.9	5.7	2.7	8
18	24.3	19.4	17.5	16.6	15.1	13.8	12.9	12.1	11.2	10.1	8.4	6.1	2.9	5
19	26.0	20.8	18.5	17.5	16.0	14.5	13.6	12.7	11.8	10.7	8.9	6.6	3.2	7
20	27.6	22.0	19.5	18.5	16.6	15.2	14.2	13.3	12.4	11.3	9.5	7.0	3.5	7
21	29.1	23.3	20.5	19.4	17.5	15.9	14.9	14.0	13.0	11.9	10.0	7.5	3.7	5
22	30.6	24.5	21.6	20.3	18.2	16.6	15.5	14.6	13.6	12.5	10.5	7.9	4.0	4
23	32.1	25.7	22.6	21.2	19.0	17.3	16.2	15.2	14.2	13.1	11.0	8.3	4.1	7
24	33.4	26.8	23.6	22.2	19.7	18.1	16.8	15.7	14.8	13.7	11.6	8.7	4.4	3
25	34.8	28.0	24.7	23.1	20.6	18.7	17.4	16.3	15.4	14.3	12.2	9.2	4.6	4
26	36.1	29.2	25.8	24.1	21.3	19.5	18.1	16.9	15.9	14.8	12.7	9.6	4.8	2
27	37.4	30.3	26.8	25.0	22.2	20.2	18.7	17.6	16.6	15.4	13.3	10.2	5.2	......
28	38.7	31.5	27.9	26.0	22.8	20.8	19.3	18.0	17.1	16.0	13.9	10.6	5.5	......
29	40.0	32.6	29.0	26.9	23.7	21.5	20.0	18.6	17.6	16.5	14.4	11.1	5.7	1
30	41.2	33.8	30.0	27.9	24.4	22.2	20.5	19.1	18.1	17.1	14.9	11.5	6.0	1
31	42.6	34.9	31.1	28.8	25.2	22.9	21.2	19.8	18.8	17.7	15.5	12.1	6.3	......
32	43.8	36.0	32.1	29.8	25.9	23.6	21.8	20.3	19.4	18.2	15.9	12.4	6.7	......
33	45.2	37.2	33.2	30.7	26.9	24.3	22.4	20.9	20.0	18.8	16.5	13.0	7.1	......
34	46.5	38.4	34.2	31.7	27.6	25.1	23.0	21.5	20.5	19.3	17.0	13.4	7.4	......
35	47.9	39.5	35.2	32.6	28.4	25.7	23.7	22.1	21.1	19.9	17.6	13.9	7.5	......
36	49.3	40.6	36.3	33.6	29.2	26.5	24.3	22.7	21.7	20.4	18.0	14.4	8.0	......
37	50.7	41.8	37.3	34.5	30.0	27.2	24.9	23.3	22.2	20.9	18.7	14.9	8.2	......
38	52.0	43.0	38.4	35.4	30.8	27.9	25.5	23.8	22.8	21.5	19.1	15.3	8.4	......
39	53.4	44.1	39.5	36.4	31.7	28.5	26.1	24.4	23.4	22.0	19.7	15.8	8.7	......
40	54.7	45.3	40.5	37.3	32.4	29.3	26.7	25.0	23.9	22.5	20.2	16.3	9.0	......
														76

TABLE 46.—*Form of basswood in the Lake States*—Continued.

90-FOOT TREES.

Diameter, breast-high.	Height above ground—feet.														Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	
	Diameter inside bark—inches.														
Inches.															*Trees.*
10	11.3	9.9	9.4	9.0	8.5	8.0	7.5	7.1	6.6	5.9	5.2	4.4	3.2	1.7	......
11	12.7	11.0	10.4	10.0	9.4	8.8	8.3	7.7	7.2	6.6	5.7	4.8	3.6	1.9	......
12	14.2	12.1	11.4	10.9	10.3	9.5	8.9	8.4	7.8	7.1	6.2	5.3	3.9	2.0	2
13	15.8	13.2	12.4	11.8	11.1	10.2	9.6	9.1	8.5	7.7	6.8	5.8	4.3	2.2	3
14	17.4	14.4	13.5	12.8	12.0	11.0	10.3	9.8	9.1	8.3	7.4	6.2	4.5	2.3	2
15	19.1	15.6	14.5	13.7	12.8	11.8	11.0	10.4	9.8	9.0	7.9	6.7	4.9	2.5	2
16	20.8	16.8	15.5	14.7	13.6	12.5	11.7	11.1	10.4	9.6	8.5	7.2	5.2	2.6	7
17	22.6	18.1	16.5	15.6	14.4	13.2	12.4	11.7	11.0	10.2	9.0	7.6	5.6	2.8	5
18	24.3	19.4	17.5	16.6	15.2	13.9	13.0	12.3	11.6	10.8	9.6	8.0	5.9	3.0	4
19	26.0	20.8	18.5	17.5	16.0	14.6	13.7	12.9	12.2	11.3	10.1	8.5	6.3	3.1	4
20	27.6	22.0	19.5	18.5	16.8	15.3	14.3	13.6	12.8	11.9	10.6	9.1	6.6	3.2	20
21	29.1	23.3	20.5	19.4	17.6	16.0	15.0	14.2	13.4	12.4	11.1	9.5	7.0	3.4	12
22	30.6	24.5	21.6	20.3	18.2	16.7	15.7	14.8	14.0	13.0	11.7	9.9	7.2	3.6	6
23	32.1	25.7	22.6	21.2	19.2	17.4	16.3	15.4	14.5	13.6	12.2	10.4	7.6	3.7	7
24	33.4	26.8	23.6	22.2	19.9	18.1	17.0	16.0	15.2	14.2	12.8	10.9	7.9	3.9	8
25	34.8	28.0	24.7	23.1	20.7	18.8	17.6	16.6	15.8	14.9	13.3	11.4	8.3	4.0	4
26	36.1	29.2	25.8	24.1	21.5	19.5	18.3	17.2	16.4	15.4	14.0	11.9	8.7	4.3	6
27	37.4	30.3	26.8	25.0	22.2	20.2	18.9	17.9	16.9	15.9	14.4	12.3	9.1	4.6	3
28	38.7	31.5	27.9	26.0	23.0	20.8	19.6	18.5	17.5	16.5	15.0	12.8	9.6	4.9	2
29	40.0	32.6	29.0	26.9	23.8	21.6	20.2	19.1	18.1	17.1	15.5	13.3	9.9	5.2	3
30	41.2	33.8	30.0	27.9	24.5	22.4	20.9	19.7	18.7	17.7	16.0	13.7	10.4	5.5	1
31	42.6	34.9	31.1	28.8	25.4	23.0	21.5	20.2	19.3	18.3	16.6	14.2	10.8	5.7	3
32	43.8	36.0	32.1	29.8	26.1	23.7	22.1	20.9	19.9	18.8	17.1	14.7	11.2	6.0	......
33	45.2	37.2	33.2	30.7	27.0	24.4	22.8	21.4	20.5	19.3	17.6	15.1	11.6	6.2	2
34	46.5	38.4	34.2	31.7	27.7	25.2	23.5	22.1	21.1	20.0	18.2	15.7	12.0	6.4	2
35	47.9	39.5	35.2	32.6	28.6	25.9	24.1	22.7	21.7	20.5	18.7	16.2	12.4	6.6	......
36	49.3	40.6	36.3	33.6	29.4	26.7	24.8	23.3	22.3	21.1	19.2	16.7	12.8	6.9	......
37	50.7	41.8	37.3	34.5	30.2	27.4	25.4	23.8	22.9	21.7	19.7	17.2	13.3	7.1	......
38	52.0	43.0	38.4	35.4	30.9	28.1	26.1	24.5	23.5	22.2	20.3	17.7	13.7	7.5	......
39	53.4	44.1	39.5	36.4	31.8	28.8	26.7	25.1	24.0	22.7	20.7	18.2	14.1	7.7	......
40	54.7	45.3	40.5	37.3	32.6	29.5	27.4	25.8	24.7	23.3	21.3	18.6	14.6	8.0	......
															108

100-FOOT TREES.

Diameter, breast high.	Height above ground—feet.															Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	
	Diameter inside bark—inches.															
In.																*Trees.*
12	14.2	12.1	11.4	10.9	10.4	9.7	9.1	8.5	8.0	7.4	6.7	5.9	4.8	3.5	1.9	1
13	15.8	13.2	12.4	11.8	11.2	10.4	9.8	9.2	8.7	8.1	7.3	6.4	5.3	3.8	2.0	......
14	17.4	14.4	13.5	12.8	12.0	11.1	10.4	9.8	9.2	8.6	7.8	6.9	5.7	4.1	2.3	1
15	19.1	15.6	14.5	13.7	12.9	11.9	11.2	10.5	9.9	9.3	8.4	7.3	6.1	4.5	2.4	4
16	20.8	16.8	15.5	14.7	13.7	12.6	11.9	11.2	10.5	9.9	9.0	7.9	6.5	4.8	2.7	1
17	22.6	18.1	16.5	15.6	14.5	13.4	12.6	11.8	11.2	10.5	9.6	8.4	6.9	5.1	2.9	2
18	24.3	19.4	17.5	16.6	15.3	14.0	13.3	12.5	11.8	11.1	10.2	9.0	7.4	5.5	3.1	3
19	26.0	20.8	18.5	17.5	16.1	14.8	14.0	13.2	12.4	11.7	10.8	9.6	7.8	5.7	3.2	3
20	27.6	22.0	19.5	18.5	16.9	15.6	14.6	13.9	13.1	12.3	11.3	10.0	8.2	6.0	3.3	3
21	29.1	23.3	20.5	19.4	17.8	16.3	15.3	14.5	13.7	12.9	11.8	10.5	8.7	6.3	3.5	4
22	30.6	24.5	21.6	20.3	18.5	17.0	15.9	15.1	14.3	13.5	12.4	11.0	9.1	6.6	3.6	3
23	32.1	25.7	22.6	21.2	19.3	17.7	16.6	15.7	14.9	14.1	12.9	11.5	9.5	6.9	3.8	3
24	33.4	26.8	23.6	22.2	20.1	18.5	17.3	16.4	15.5	14.6	13.4	12.0	9.9	7.2	4.0	7
25	34.8	28.0	24.7	23.1	20.9	19.0	17.9	16.9	16.1	15.3	14.0	12.5	10.4	7.5	4.1	6
26	36.1	29.2	25.8	24.1	21.7	19.8	18.5	17.5	16.7	15.8	14.6	13.0	10.8	7.7	4.2	7
27	37.4	30.3	26.8	25.0	22.6	20.4	19.2	18.1	17.4	16.5	15.2	13.5	11.2	8.0	4.3	1
28	38.7	31.5	27.9	26.0	23.2	21.2	19.8	18.8	18.0	17.0	15.7	14.1	11.6	8.2	4.5	4
29	40.0	32.6	29.0	26.9	24.0	21.9	20.5	19.4	18.5	17.6	16.2	14.5	12.1	8.6	4.6	2
30	41.2	33.8	30.0	27.9	24.7	22.7	21.1	20.0	19.2	18.1	16.8	15.0	12.4	8.9	4.8	2
31	42.6	34.9	31.1	28.8	25.5	23.3	21.8	20.6	19.8	18.8	17.4	15.6	12.9	9.1	4.9	3
32	43.8	36.0	32.1	29.8	26.2	24.1	22.4	21.2	20.4	19.3	17.9	16.1	13.4	9.5	5.2	2
33	45.2	37.2	33.2	30.7	27.0	24.7	23.1	21.9	21.0	20.0	18.6	16.6	13.8	9.9	5.4	1
34	46.5	38.4	34.2	31.7	27.8	25.5	23.7	22.4	21.6	20.5	19.0	17.1	14.3	10.3	5.7	1
35	47.9	39.5	35.2	32.6	28.6	26.1	24.4	23.1	22.2	21.2	19.6	17.6	14.8	10.7	5.9	......
36	49.3	40.6	36.3	33.6	29.3	26.9	25.0	23.7	22.7	21.6	20.1	18.1	15.2	11.1	6.2	......
37	50.7	41.8	37.3	34.5	30.1	27.5	25.7	24.4	23.5	22.4	20.7	18.7	15.7	11.4	6.4	......
38	52.0	43.0	38.4	35.4	30.9	28.3	26.4	25.0	24.1	22.9	21.3	19.2	16.2	11.9	6.6	......
39	53.4	44.1	39.5	36.4	31.6	28.9	27.0	25.6	24.7	23.6	21.9	19.7	16.6	12.1	6.7	......
40	54.7	45.3	40.5	37.3	32.4	29.7	27.7	26.2	25.3	24.1	22.5	20.3	17.1	12.5	6.9	......
																64

TABLE 46.—*Form of basswood in the Lake States*—Continued.

110-FOOT TREES.

Diameter, breast high.	Height above ground—feet.																Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.9	
	Diameter inside bark—inches.																
Inches																	*Trees.*
14	17.4	14.4	13.5	12.8	12.1	11.3	10.7	10.2	9.6	8.9	8.1	7.3	6.4	5.2	3.8	2.2	......
15	19.1	15.6	14.5	13.7	12.9	12.0	11.5	10.9	10.3	9.5	8.7	7.9	6.9	5.7	4.0	2.3	......
16	20.8	16.8	15.5	14.7	13.7	12.7	12.0	11.5	10.9	10.1	9.3	8.4	7.4	6.0	4.2	2.4	......
17	22.6	18.1	16.5	15.6	14.6	13.5	12.8	12.2	11.5	10.8	9.9	9.0	7.9	6.5	4.4	2.6	1
18	24.3	19.4	17.5	16.6	15.4	14.2	13.4	12.8	12.1	11.4	10.6	9.6	8.4	6.8	4.7	2.7	1
19	26.0	20.8	18.5	17.5	16.3	14.9	14.1	13.5	12.8	12.0	11.2	10.1	8.9	7.2	4.9	2.8	......
20	27.6	22.0	19.5	18.5	17.0	15.6	14.8	14.1	13.4	12.6	11.7	10.7	9.3	7.5	5.2	2.9	......
21	29.1	23.3	20.5	19.4	17.9	16.4	15.5	14.7	14.0	13.2	12.3	11.2	9.8	7.9	5.5	3.1	......
22	30.6	24.5	21.6	20.3	18.7	17.1	16.1	15.3	14.6	13.8	13.0	11.8	10.3	8.2	5.8	3.3	1
23	32.1	25.7	22.6	21.2	19.5	17.8	16.9	16.1	15.2	14.5	13.5	12.3	10.7	8.6	6.1	3.5	......
24	33.4	26.8	23.6	22.2	20.3	18.5	17.5	16.6	15.9	15.1	14.1	12.9	11.2	9.0	6.4	3.6	1
25	34.8	28.0	24.7	23.1	21.0	19.2	18.1	17.2	16.5	15.7	14.7	13.4	11.6	9.3	6.6	3.9	......
26	36.1	29.2	25.8	24.1	21.8	19.9	18.8	17.9	17.1	16.3	15.3	14.0	12.1	9.7	7.0	4.1	1
27	37.4	30.3	26.8	25.0	22.6	20.6	19.5	18.5	17.7	17.0	15.8	14.5	12.6	10.0	7.1	4.2	4
28	38.7	31.5	27.9	26.0	23.4	21.3	20.1	19.1	18.3	17.5	16.4	15.0	13.0	10.3	7.5	4.3	3
29	40.0	32.6	29.0	26.9	24.1	22.0	20.8	19.7	18.9	18.2	17.0	15.5	13.5	10.7	7.7	4.4	......
30	41.2	33.8	30.0	27.9	24.9	22.7	21.4	20.3	19.6	18.8	17.6	16.0	13.9	11.1	8.0	4.7	......
31	42.6	34.9	31.1	28.8	25.7	23.4	22.1	21.0	20.2	19.4	18.1	16.6	14.3	11.4	8.2	4.8	2
32	43.8	36.0	32.1	29.8	26.3	24.2	22.7	21.6	20.8	19.9	18.7	17.1	14.8	11.7	8.5	4.9	1
33	45.2	37.2	33.2	30.7	27.3	24.8	23.4	22.3	21.4	20.5	19.3	17.7	15.3	12.1	8.7	5.0	......
34	46.5	38.4	34.2	31.7	27.9	25.6	24.0	22.9	22.0	21.1	19.9	18.3	15.8	12.5	9.0	5.2	1
35	47.9	39.5	35.2	32.6	28.7	26.3	24.8	23.6	22.7	21.8	20.5	18.8	16.3	12.9	9.2	5.4	......
36	49.3	40.6	36.3	33.6	29.4	27.1	25.3	24.2	23.4	22.5	21.2	19.4	16.9	13.3	9.5	5.6	......
37	50.7	41.8	37.3	34.5	30.3	27.7	26.1	24.9	24.0	23.0	21.7	20.0	17.3	13.7	9.8	5.7	1
38	52.0	43.0	38.4	35.4	31.1	28.5	26.7	25.5	24.7	23.7	22.3	20.5	17.9	14.1	10.0	5.9	......
39	53.4	44.1	39.5	36.4	32.0	29.2	27.5	26.3	25.3	24.2	22.8	21.1	18.4	14.6	10.4	5.9	......
40	54.7	45.3	40.5	37.3	32.7	30.0	28.1	26.9	26.0	24.9	23.5	21.7	19.0	15.0	10.6	6.1	......
																	17

120-FOOT TREES.

Diameter, breast high.	Height above ground—feet.																	Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	66.2	58.05	74.35	82.5	90.65	98.8	106.95	
	Diameter inside bark—inches.																	
In.																		*Trees.*
16	20.8	16.8	15.5	14.7	13.7	13.0	12.4	11.7	11.1	10.4	9.7	8.9	8.0	6.9	5.5	4.0	2.5	......
17	22.6	18.1	16.5	15.6	14.6	13.6	13.0	12.4	11.8	11.1	10.3	9.4	8.5	7.3	5.8	4.2	2.6	......
18	24.3	19.4	17.5	16.6	15.4	14.5	13.7	13.0	12.4	11.7	10.9	10.0	9.0	7.7	6.1	4.4	2.7	......
19	26.0	20.8	18.5	17.5	16.3	15.1	14.3	13.7	13.1	12.3	11.5	10.5	9.5	8.1	6.3	4.6	2.8	......
20	27.6	22.0	19.5	18.5	17.1	15.9	15.0	14.3	13.6	12.9	12.1	11.1	9.9	8.5	6.5	4.7	2.9	......
21	29.1	23.3	20.5	19.4	18.0	16.5	15.6	14.9	14.3	13.6	12.7	11.7	10.5	8.9	6.8	4.9	3.0	......
22	30.6	24.5	21.6	20.3	18.8	17.3	16.2	15.6	15.0	14.3	13.3	12.3	10.9	9.2	7.1	5.1	3.2	......
23	32.1	25.7	22.6	21.2	19.6	18.0	17.0	16.2	15.6	14.8	13.9	12.8	11.5	9.7	7.3	5.3	3.3	......
24	33.4	26.8	23.6	22.2	20.4	18.7	17.6	16.9	16.2	15.4	14.5	13.4	12.0	10.1	7.6	5.5	3.4	......
25	34.8	28.0	24.7	23.1	21.2	19.4	18.3	17.5	16.9	16.0	15.1	14.1	12.6	10.5	8.0	5.8	3.5	......
26	36.1	29.2	25.8	24.1	21.9	20.2	18.9	18.2	17.5	16.7	15.7	14.6	13.0	10.8	8.4	6.1	3.7	1
27	37.4	30.3	26.8	25.0	22.7	20.8	19.7	18.8	18.1	17.3	16.3	15.2	13.6	11.3	8.7	6.3	3.8	......
28	38.7	31.5	27.9	26.0	23.5	21.5	20.3	19.5	18.7	17.9	16.9	15.8	14.1	11.6	9.0	6.6	4.0	......
29	40.0	32.6	29.0	26.9	24.4	22.2	21.0	20.1	19.3	18.6	17.5	16.3	14.6	12.1	9.4	6.8	4.2	......
30	41.2	33.8	30.0	27.9	25.1	23.0	21.6	20.8	20.0	19.1	18.1	16.9	15.1	12.4	9.8	7.1	4.3	......
31	42.6	34.9	31.1	28.8	25.9	23.6	22.4	21.4	20.7	19.8	18.7	17.5	15.6	12.9	10.0	7.3	4.5	......
32	43.8	36.0	32.1	29.8	26.6	24.3	23.0	22.1	21.3	20.4	19.3	18.0	16.1	13.2	10.4	7.5	4.6	......
33	45.2	37.2	33.2	30.7	27.4	25.0	23.7	22.8	21.9	21.0	19.9	18.6	16.6	13.7	10.7	7.7	4.8	......
34	46.5	38.4	34.2	31.7	28.1	25.8	24.3	23.3	22.5	21.6	20.5	19.2	17.1	14.1	11.0	8.0	4.9	......
35	47.9	39.5	35.2	32.6	29.0	26.5	25.1	24.1	23.3	22.3	21.1	19.7	17.6	14.5	11.3	8.1	5.0	1
36	49.3	40.6	36.3	33.6	29.7	27.3	25.8	24.8	23.8	22.8	21.7	20.3	18.1	14.9	11.7	8.5	5.2	......
37	50.7	41.8	37.3	34.5	30.5	27.9	26.5	25.4	24.5	23.5	22.3	20.9	18.6	15.4	12.0	8.7	5.3	......
38	52.0	43.0	38.4	35.4	31.1	28.8	27.2	26.1	25.2	24.1	22.9	21.5	19.2	15.8	12.3	9.0	5.5	......
39	53.4	44.1	39.5	36.4	32.0	29.4	28.0	26.9	25.9	24.8	23.5	22.1	19.7	16.2	12.6	9.2	5.6	......
40	54.7	45.3	40.5	37.3	32.7	30.3	28.7	27.5	26.5	25.4	24.2	22.7	20.2	16.6	12.9	9.4	5.7	......
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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 286

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER September 27, 1915

STRENGTH TESTS OF STRUCTURAL TIMBERS TREATED BY COMMERCIAL WOOD-PRESERVING PROCESSES.

By H. S. Betts and J. A. Newlin, *Engineers in Forest Products, Forest Products Laboratory.*

CONTENTS.

OBJECT OF THE TESTS.

This bulletin presents the results of tests made by the Forest Service, in cooperation with the Illinois Central Railway and one eastern and two western wood-preserving companies, to determine how the strength of bridge stringers is affected by commercial creosote treatments. To do this, comparison was made between the strength of treated and untreated stringers of the same size and quality. The test timbers were selected by representatives of the Forest Service from stock furnished by the cooperators. The Forest Service requested that the treatments given the timbers by each of the cooperators be that used in its regular commercial practice. A Forest Service representative was present during the treatments and kept a record of the various conditions to which the material was subjected. The woods used were loblolly pine, longleaf pine, and Douglas fir. After treatment the loblolly and longleaf pine were shipped to the Forest Service timber-testing laboratory at Lafayette, Ind.,[1] and the Douglas fir to the Forest Service timber-testing station, Seattle, Wash.[2]

[1] Formerly conducted in cooperation with Purdue University.

[2] Conducted in cooperation with the University of Washington.

Note.—This report is of interest to users of timber where strength is an important consideration.

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MATERIAL TESTED.

The material for test was selected from regular stock, in the form of sticks 8 inches by 16 inches in section and from 28 to 32 feet in length. The sticks were sorted in pairs, with the object of having those in each pair as alike as possible. At the time of treatment each stick was cut into two stringers of equal length, making four test stringers in each group, two butt cuts and two second or top cuts. The groups were handled as shown in figure 1, the butt ends in one group being treated and the top ends in the next.

LONGLEAF AND LOBLOLLY PINE.

The longleaf and loblolly pine timber were cut in southern Mississippi and Louisiana. About five months elapsed between the time

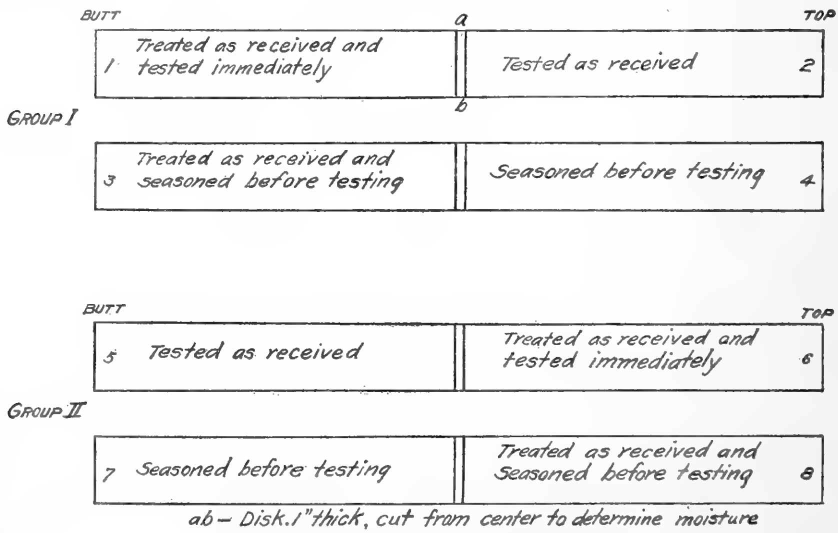

FIG. 1.—Method of cutting and marking test material.

the logs were sawed and the time of treatment, during four months of which the pieces were seasoned in an open pile. The treated stringers were en route to Lafayette, Ind., for over a month. Upon arrival they were close piled under shelter until the tests were started about a month later. The pieces as selected were 8 inches by 16 inches in section by 28 feet long. The material classed as "longleaf" was high-grade timber, considered as first-class structural material by the railway officials, and that classed as "loblolly" as less valuable. The longleaf had only a small per cent of sap and was of comparatively slow growth, while the loblolly averaged over 30 per cent sapwood, was of more rapid growth, and contained more knots. The number of test stringers 14 feet long was as follows:

Longleaf:
- 5 treated partially air dry and tested.
- 5 tested partially air dry.
- 5 treated partially air dry, seasoned, and tested.
- 5 seasoned and tested.

Loblolly:
- 5 treated partially air dry and tested.
- 5 tested partially air dry.
- 5 treated partially air dry, seasoned, and tested.
- 5 seasoned and tested.

DOUGLAS FIR.

The material was selected at two western mills. In both cases the test timbers were shipped to the creosoting companies within a few days after they were sawed from logs at the mill, and were treated within a few days after arrival at the creosoting plants. The pieces as selected were 8 inches by 16 inches in section and 32 feet long, and included three grades of material—select, merchantable, and common, as classified by the grading rules of the West Coast Lumber Manufacturers' Association. It is customary to use only select and merchantable timbers in permanent structures. These pieces were cut in two just before treatment, so that the test stringers measured 16 feet. Two processes of treatment were used, the "boiling" process and the "steaming" process. The material which was seasoned before testing was piled in a shed with open sides. The number of 16-foot test stringers used in studying the effect of the two processes, and their condition when treated and tested, was as follows:

Boiling process:
- 20 treated green and tested.
- 20 tested green.
- 19 treated green, seasoned, and tested.
- 19 seasoned and tested.

Steaming process:
- 15 treated green and tested.
- 15 tested green.
- treated green, air seasoned, and tested.
- seasoned and tested.

METHODS OF TREATMENT.

The preservative treatments to which the three species of structural timber were subjected were briefly as follows:

LOBLOLLY PINE.[1]

Steamed for 4 hours under 29 pounds pressure; vacuum of 26 inches applied for 1 hour; cylinder filled with creosote and pressure of 125 pounds applied for 4½ hours at a temperature of 140° F.; vacuum of 23½ inches applied for ¼ hour. Absorption of oil, 13½ pounds per cubic foot of wood.

[1] Run made Mar. 4, 1908.

LONGLEAF PINE.[1]

Steamed for 6 hours at 30 pounds pressure; vacuum of 26 inches applied for 1 hour; cylinder filled with creosote and pressure of 128 pounds applied for 5½ hours at a temperature of 140° F. Absorption, 12¾ pounds per cubic foot of wood.

DOUGLAS FIR.[1]

Boiling process.—Boiled in creosote for 21¾ hours at temperature of 215° F.;[2] loss of moisture during boiling, 1.2 pounds per cubic foot of wood; pressure raised from 0 to 145 pounds per square inch in 5¾ hours; temperature about 190° F. Absorption of oil, 11.2 pounds per cubic foot of wood, as determined by measuring tank readings.

Steaming process.—Steamed at 90 pounds pressure per square inch for 4¼ hours; temperature about 325° F.; vacuum of 20 inches applied for 18½ hours; temperature 220° F. at end of period; cylinder filled with oil and pressure raised from 0 to maximum pressure of 140 pounds per square inch; pressure period, 2¼ hours; temperature of the oil, about 208° F. Absorption, 3.1 pounds per cubic foot of wood, as figured from increase in original weight of stringers. The stringers were not weighed after steaming, so that the probable loss can not be taken into account in computing the absorption.

METHOD OF TESTING.

The stringers were tested in bending by supporting them at the ends and applying the load at two points located one-third of the span from each of the end supports. This system corresponds closely to conditions of practice. In testing the beams the load was applied gradually and a record kept of the deflections corresponding to regular load increments. Four factors were calculated from the data derived from each bending test, all in terms of pounds per square inch:

FIBER STRESS AT ELASTIC LIMIT.

This is the greatest stress that can occur in a beam loaded with an external load from which it will recover without permanent deflection.

MODULUS OF RUPTURE.

This is the greatest computed stress in a beam under a breaking load.

MODULUS OF ELASTICITY.

This is a factor computed from the relation between load and deflection within the elastic limit, and represents the stiffness of the wood.

LONGITUDINAL SHEAR.

This is the stress tending to split the beam lengthwise along its neutral plane[3] when under maximum load.

---

[1] Run made Mar. 5, 1908.

[2] Some time after the treatments were made it was reported by the treating-plant officials that the thermometer giving this reading registered 40° F. too low.

[3] Plane between upper and lower halves when beam is horizontal.

MOISTURE DETERMINATIONS.

Moisture determinations on the untreated wood were made by taking either borings or disks from the tested pieces, weighing them, and then drying them to constant weight. The difference between the original weight and the dry weight divided by the dry weight times 100 is taken as the per cent of moisture at the time of test. Disks taken from the untreated stringers were cut into a number of pieces and the moisture separately determined for each in order to find the distribution of moisture throughout the cross section. The method of dividing the disks is shown in figure 2. The moisture determinations made on treated specimens were handled by distilling the treated shavings cut from the test pieces with water-saturated xylol. For such determinations a definite quantity of treated borings was taken. In all cases a corresponding volume of untreated shavings was obtained, and the dry weight of this sample determined as a basis for computing the moisture content of the treated sample. All test pieces were weighed and measured, the number of rings counted on a radial line, and the per cent of summerwood and sap determined.[1] Sketches were made and photographs taken, showing the size and location of knots, checks, and shakes.

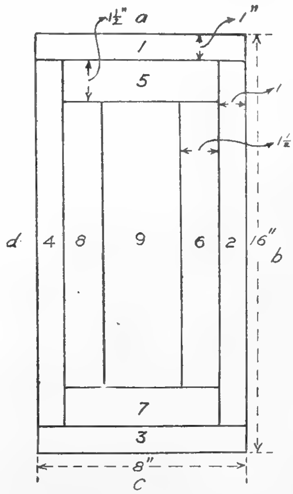

FIG. 2.—Moisture distribution disk for 8-inch by 16-inch stringer.

TESTS ON SMALL STICKS.

After failure occurred in the stringers, small pieces 2 inches by 2 inches in section and 3 feet long were cut from the unbroken portions. These small pieces were selected so as to be free from defects and with straight grain. Their location in a cross section of the stringer was noted, so that data could be secured on the relative strength of the inner and outer portions. The tests of small pieces included bending tests on specimens 2 by 2 by 30 inches, compression tests in which specimens 2 by 2 by 8 inches were crushed endwise parallel with the grain, compression tests at right angles to the grain, and shearing tests in which a projecting portion of a small block was sheared off parallel to the grain while the main portion of the block was held firm.

[1] Determinations of summerwood and sap were omitted for some of the Douglas fir.

RESULTS OF TESTS.

The results of the bending tests on the natural and treated stringers are shown in figures 3 to 7.

The diagrams were made by first plotting the values for modulus of rupture of the natural beams (solid lines) arranged from the highest to lowest, beginning with the highest value on the left at the top of the figure. The modulus of rupture of the treated half (dotted lines) of the test pieces was then plotted in the same vertical line as the untreated pieces. The two values are marked to distinguish butts (*B*) from corresponding tops (*T*). The other values (fiber stress at elastic limit and modulus of elasticity) for the same beams are plotted in the same vertical lines.

Conclusions should not be drawn regarding the comparative effect of creosoting on the strength of the different woods, since they were not treated under similar conditions. It should also be kept in mind that the test material was not selected for the purpose of comparing the various species.

LOBLOLLY PINE.

Figure 3 gives a comparison of the strength and stiffness of natural and treated loblolly pine stringers for partially air-dry and seasoned material. In drawing conclusions from the diagrams it should be kept in mind that butt stringers are naturally stronger than second-cut or top stringers. This point was considered when the method of selecting the test material was determined upon and butts and tops were arranged to alternate in serving as treated and untreated material. It will be noted from figure 3 that when the butts were treated the breaking strength of the butts and tops fell rather close together, while when the tops were treated the breaking strength values were much farther apart. This shows an evident weakening due to the treatment, even when the lower breaking strength of the top stringers is taken into account. The tests are too few to make a definite statement as to the amount of weakening for the specific treatment under consideration. It is probably not more than 17 per cent. The fiber strength at elastic limit and the stiffness both show a greater weakening due to treatment than does the breaking strength. The weakening is more marked in both strength and stiffness in the air dry than in the partially air-dry stringers. Both the treated and untreated stringers showed a strength about 30 per cent greater in the seasoned material than in the partially air-dry material.

LONGLEAF PINE.

In figure 4 the strength of treated and untreated longleaf pine stringers is compared for both partially air-dry and seasoned material. It does not appear that the breaking strength was affected by the treatment used with these stringers. There is a slight reduction in the average strength at elastic limit and stiffness. In the air-seasoned beams the untreated butt cuts were higher in strength and stiffness than the treated top cuts, but, on the other hand, the untreated top cuts fell below the treated butts in strength and stiffness in nearly every case. In the partially seasoned stringers the treated and untreated material falls together somewhat more closely.

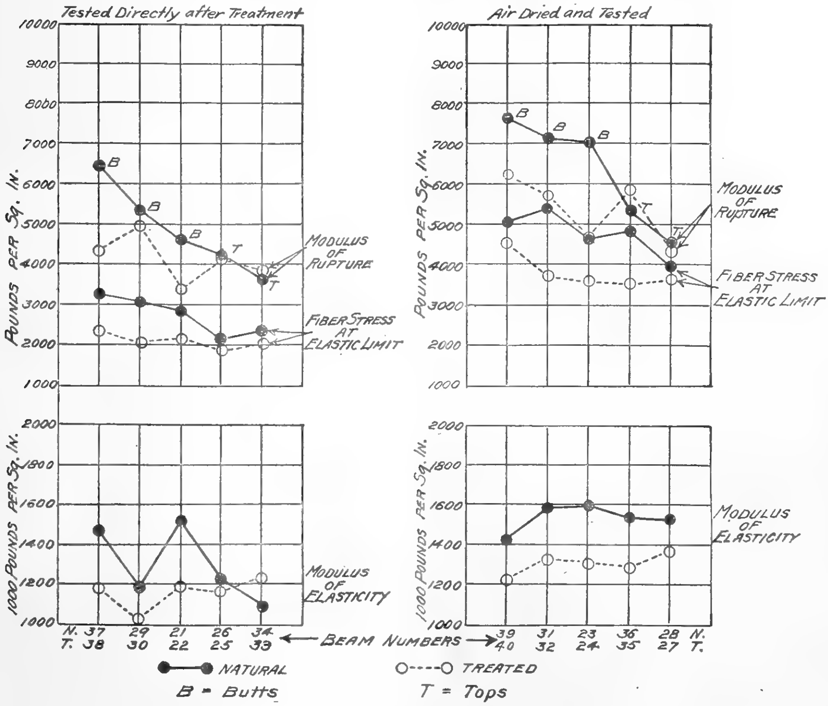

FIG. 3.—Effect of preservative treatment on the strength and stiffness of loblolly-pine stringers treated partially air dry.

DOUGLAS FIR.

Figures 5 and 6 show the strength and stiffness of treated and untreated stringers of green and seasoned Douglas fir, respectively, treated by the so-called "boiling" process as used in this case. There appears to be a marked weakening of the breaking strength with the particular treatment used. The average breaking strength of the stringers tested green and after seasoning is 33 per cent and 39 per cent, respectively, less than the average strength of the natural stringers. The fiber stress at elastic limit also appears to be reduced, although to a somewhat less extent. In the green material no weakening is apparent in the stiffness. The seasoned stringers, however, show a falling off in stiffness in the treated material.

Figure 7 shows the strength and stiffness of green[1] Douglas fir treated by the so-called "steaming" process. The breaking strength

[1] The air-seasoned material is not yet tested, July, 1915.

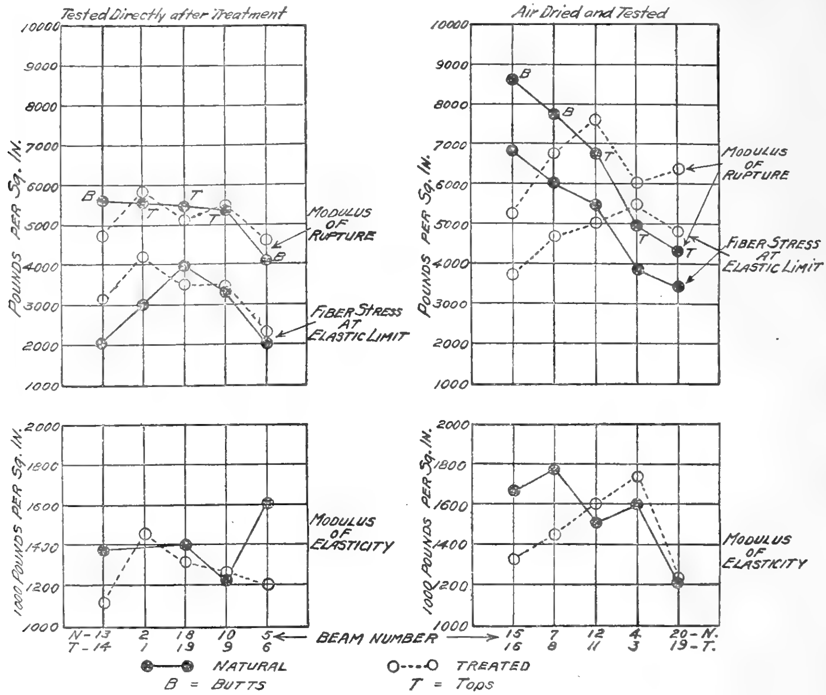

FIG. 4.—Effect of preservative treatment on the strength and stiffness of longleaf-pine stringers treated partially dry.

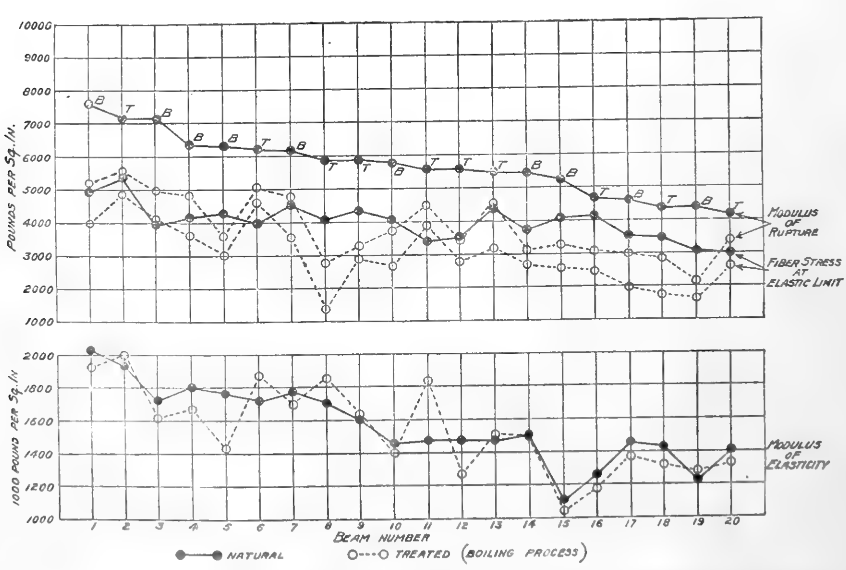

FIG. 5.—Effect of "boiling process" of preservative treatment on the strength and stiffness of Douglas-fir stringers treated green and tested without seasoning.

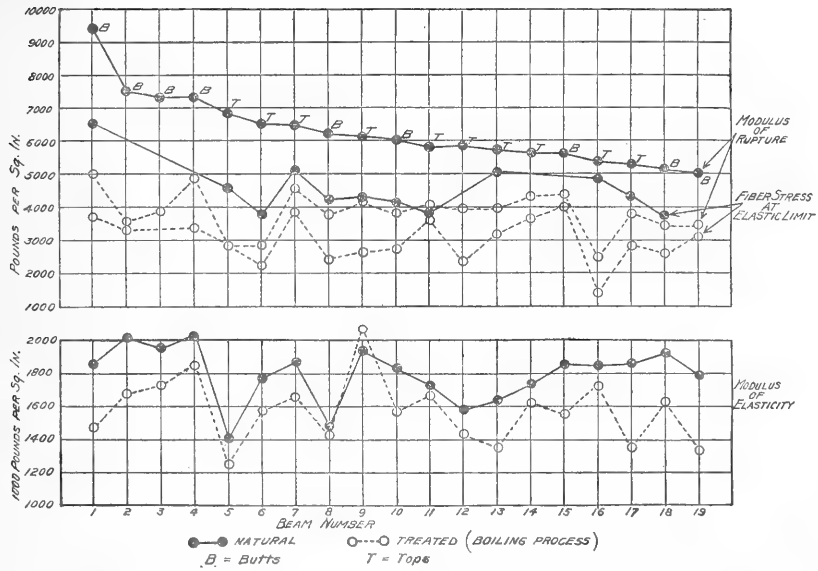

FIG. 6.—Effect of "boiling process" of preservative treatment on the strength and stiffness of Douglas-fir stringers treated green, air seasoned and tested.

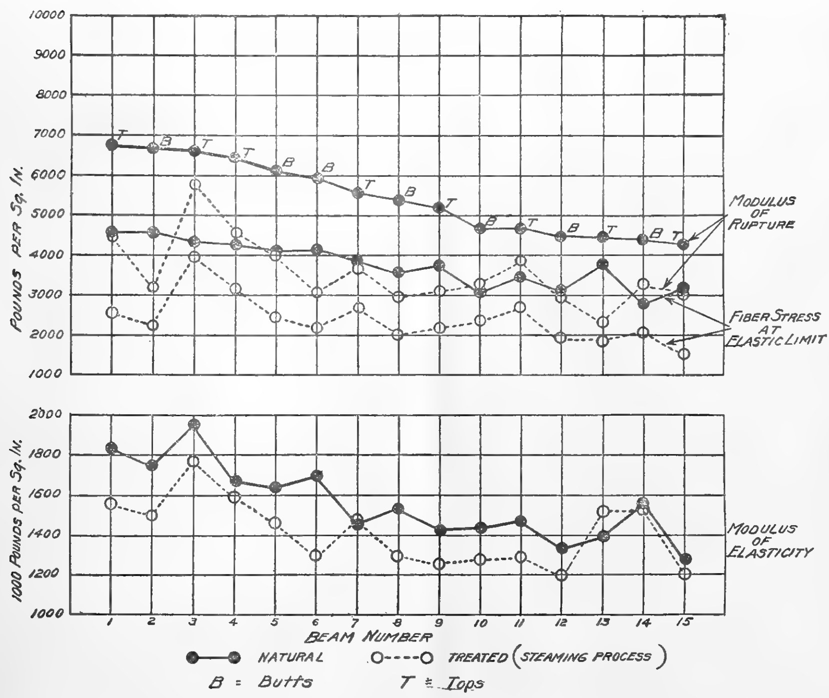

FIG. 7.—Effect of "steaming process" of preservative treatment on the strength and stiffness of Douglas-fir stringers treated green and tested without seasoning.

TABLE 1.—*Strength and stiffness of natural and treated stringers.*

Species and condition.	Rings per inch.		Summerwood (per cent).		Sap (per cent).		Moisture (per cent).		Modulus of rupture (pounds per square inch).		Modulus of elasticity (1,000 pounds per square inch).		Fiber stress at elastic limit (pounds per square inch).		Shearing stress at maximum load (pounds per square inch).	
	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.
Longleaf pine:																
Partially air dry, 10 tests—																
Average	14.2	14.0	38.8	38.8	5	2	27.6	26.2	5,151	5,132	1,409	1,275	3,346	2,898	408	399
Maximum	17.0	15.5	50.0	54.3	21	11	29.1	30.3	5,575	5,830	1,617	1,462	4,180	3,970	438	452
Minimum	10.8	11.3	28.0	29.3	0	0	25.9	22.1	4,150	4,600	1,235	1,113	2,390	2,050	325	357
Air dry, 10 tests—																
Average	19.2	18.0	38.2	41.6	11	10	19.0	21.8	6,466	6,376	1,561	1,471	4,950	4,762	499	499
Maximum	23.0	19.7	45.3	44.0	21	17	19.6	23.4	8,600	7,620	1,767	1,742	6,040	5,530	658	595
Minimum	17.3	16.3	33.3	38.7	3	2	18.4	21.1	4,280	5,260	1,236	1,227	3,450	3,740	320	408
Loblolly pine:																
Partially air dry, 10 tests—																
Average	5.8	5.9	43.2	43.2	8	14	35.7	49.4	4,858	4,150	1,296	1,155	2,738	2,080	402	339
Maximum	7.3	7.3	52.5	46.0	22	35	54.1	70.2	6,440	4,960	1,515	1,234	3,250	2,340	535	409
Minimum	4.8	4.3	36.8	35.8	0	0	24.1	36.0	3,680	3,390	1,089	1,030	2,160	1,830	301	275
Air dry, 10 tests—																
Average	6.8	7.3	34.5	37.2	40	40	18.2	23.8	6,392	5,380	1,534	1,297	4,806	3,808	507	437
Maximum	10.3	12.3	40.0	45.0	78	70	18.8	29.6	7,680	6,270	1,596	1,367	5,430	4,580	624	509
Minimum	3.7	3.7	33.0	30.3	7	5	17.5	18.7	4,510	4,360	1,430	1,238	3,910	3,520	362	361
Douglas fir:																
Boiling process—																
Green, 40 tests—																
Average	11.0	11.2	45.2	45.4	0	0	33.6	28.5	5,690	3,820	1,569	1,542	3,980	2,980	381	253
Maximum	17.7	19.0	57.0	61.0	......	......	38.5	32.8	7,590	5,540	2,070	2,001	5,340	4,850	514	364
Minimum	4.7	5.4	35.0	37.0	......	......	28.3	24.3	4,120	2,090	1,115	1,028	2,950	1,370	277	137
Air dry, 38 tests—																
Average	11.5	11.3	39.5	38.2	0	0	15.3	19.5	6,240	3,860	1,809	1,560	4,560	2,840	407	254
Maximum	18.5	19.6	52.0	47.0	......	......	17.8	23.0	9,440	4,930	2,402	2,062	6,630	4,010	615	324
Minimum	6.6	6.2	30.0	31.0	......	......	13.4	16.4	3,990	2,510	1,400	1,252	3,750	1,360	256	165
Steaming process—																
Green, 30 tests—																
Average	14.7	14.0	36.6	34.2	0	0	37.5	33.0	5,430	3,540	1,557	1,412	3,740	2,370	366	237
Maximum	22.2	20.9	53.8	50.0	......	......	45.9	36.8	6,710	5,740	1,945	1,778	4,560	3,930	454	384
Minimum	5.9	5.1	26.3	27.5	......	......	32.4	29.3	4,280	2,310	1,277	1,195	2,730	1,490	291	150
Air dry, — tests—																
Average	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Maximum	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Minimum	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

and fiber stress at the elastic limit was considerably less in the treated material (35 and 36 per cent, respectively), and the stiffness was slightly less.

Table 1 gives the average values of the strength functions shown in the diagrams, together with the highest and lowest values and some additional data.

SMALL PIECES CUT FROM STRINGERS.

Table 2 gives the average strength and stiffness of the small pieces cut from the main beams for both treated and natural material of the three species under test. The average values of the small pieces cut from the outside portions of the main beams and the average values of the small pieces cut from the interior portions are also given. No moisture determinations were made on the small pieces cut from the treated longleaf and loblolly pine timbers. The determinations for moisture in various parts of the cross sections of the treated timbers of these two species indicate that in general they contained slightly more moisture than the natural pieces. The treated sticks are in general weaker than the natural sticks, but the difference is slight except for partially air-dry loblolly pine. Part of the apparent loss in strength of the treated material may be ascribed to its higher moisture content.

In the Douglas fir treated by the boiling process and tested green, the average for the outside sticks shows a decrease in strength over the natural, with but little difference in stiffness. As compared with the natural sticks the treated sticks cut from the interior of the main beams showed a more marked drop in strength and stiffness. The air-dry material in all cases showed a decided decrease in the strength of the treated sticks. The decrease in stiffness was less marked. Part of this decrease may be accounted for by the higher moisture content of the treated pieces.

TABLE 2.—*Strength and stiffness of small pieces—natural and treated—cut from the inside and outside portions of longleaf pine, loblolly pine, and Douglas fir stringers.*

Species, condition, and locality.	Number of tests.		Moisture (per cent).		Rings per inch.		Modulus of rupture (pounds per square inch).		Fiber stress of elastic limit (pounds per square inch).		Modulus of elasticity (1,000 pounds per square inch).	
	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.
Longleaf pine:												
Partially air dry—												
All	28	29	21.5	......	19.2	18.3	9,507	9,036	5,623	5,365	1,493	1,434
Outside	24	24	21.0	......	19.6	19.3	9,455	9,046	5,587	5,376	1,485	1,428
Inside	4	5	24.6	......	14.6	14.4	9,978	8,870	5,953	5,088	1,581	1,464
Air dry—												
All	23	23	12.8	......	19.9	19.6	13,520	11,418	8,070	6,824	1,663	1,508
Outside	18	17	13.0	......	20.2	18.1	13,109	11,208	8,060	6,855	1,641	1,489
Inside	5	6	12.6	......	18.5	14.2	14,378	11,495	8,153	9,543	1,714	1,527
Loblolly pine:												
Partially air dry—												
All	30	28	20.3	......	6.4	6.4	8,605	6,571	5,109	3,531	1,350	1,104
Outside	24	22	19.8	......	6.9	6.9	8,599	6,221	5,120	3,294	1,339	1,086
Inside	6	6	22.2	......	4.6	5.5	8,592	8,148	5,010	4,560	1,365	1,289
Air dry—												
All	30	26	12.0	......	7.2	7.4	12,491	12,182	7,502	7,611	1,605	1,603
Outside	24	21	12.0	......	7.6	7.6	12,382	12,122	7,434	7,644	1,607	1,609
Inside	6	5	11.8	......	5.7	5.8	13,003	12,157	7,713	7,145	1,595	1,550
Douglas fir:												
Boiling process—												
Green—												
All	48	38	30.1	27.5	10.7	12.6	7,923	6,216	4,450	3,434	1,595	1,486
Outside	24	19	29.6	......	11.7	13.9	8,041	6,862	4,407	3,897	1,617	1,570
Inside	24	19	30.6	......	9.6	11.4	7,805	5,571	4,493	2,971	1,583	1,401
Air dry—												
All	66	54	15.6	......	13.2	13.1	10,608	6,598	6,546	4,003	1,778	1,624
Outside	33	27	14.8	......	14.1	13.6	10,929	6,721	6,953	4,021	1,787	1,617
Inside	33	27	16.4	......	12.2	12.6	10,287	6,475	6,138	3,985	1,770	1,632
Steaming process—												
Green—												
All	...	...	......	......	......	......	....	....	......	......	......	......
Outside	...	...	......	......	......	......	....	....	......	......	......	......
Inside	...	...	......	......	......	......	....	....	......	......	......	......
Air dry—												
All	...	...	......	......	......	......	....	....	......	......	......	......
Outside	...	...	......	......	......	......	....	....	......	......	......	......
Inside	...	...	......	......	......	......	....	....	......	......	......	......

SPECIAL TESTS ON SMALL PIECES.

Table 3 gives a condensed summary of the results of a special series of tests on small clear speciments (2 by 2 inches in section) of Douglas fir, longleaf pine, and shortleaf pine. The tests were made at the Forest Products Laboratory to study the effect of the various steps used in the treatment of the full-sized stringers. Eight sticks were subjected to each of the processes shown in Table 3. One-half of the sticks were tested shortly after treatment and one-half after they had been piled in the laboratory long enough (5 months) to reach a practically constant weight.

All the processes caused a reduction in the strength values of the unseasoned material of the three species with, in most cases, a recovery after seasoning, except in the tension tests. In these the weakening in the unseasoned material remained after seasoning in all processes but the creosote bath.

TABLE 3.—*Effect of various treatments on small clear sticks (results expressed*[1] *in per cent of strength of untreated material).*

	Steamed at 20 pounds 5 hours.		Steamed at 20 pounds 5 hours; 26-inch vacuum 1 hour.		Steamed at 20 pounds 5 hours; 26-inch vacuum 1 hour; creosote, 120 pounds pressure, 4½ hours.		Creosote at atmospheric pressure, 200° F., 27 hours.		Creosote bath at atmospheric pressure, 200° F., 27 hours; creosote at 145 pounds pressure, 180° F., 1¾ hours.	
	Unseasoned.	Air dry.	Unseasoned.	Air dry.	Unseasoned.	Air dry.	Unseasoned.	Air dry.	Unseasoned.	Air dry.
Bending:										
Modulus of rupture—										
Douglas fir	74	96	78	93	83	86	92	89	86	98
Longleaf pine	83	100	......	......	80	85	......	......	81	93
Shortleaf pine	73	107	72	98	84	104	96	108	89	106
Modulus of elasticity—										
Douglas fir	87	100	84	100	95	98	97	105	93	99
Longleaf pine	94	106	......	......	91	99	......	......	92	108
Shortleaf pine	84	104	92	103	96	105	112	102	96	100
Compression:										
Maximum crushing strength—										
Douglas fir	68	102	76	88	80	97	83	102	90	112
Longleaf pine	79	102	......	......	82	76	......	......	80	87
Shortleaf pine	70	101	71	101	82	104	89	103	89	109
Shear with grain—										
Douglas fir	72	93	74	96	74	100	91	118	86	125
Longleaf pine	77	118	......	......	73	......	......	......	74	115
Shortleaf pine	71	107	74	105	80	108	88	114	90	115
Tension perpendicular to grain—										
Douglas fir	57	69	54	64	48	57	47	116	63	117
Longleaf pine	42	47	......	......	60	......	......	......	61	67
Shortleaf pine	70	81	71	73	71	64	95	130	79	88
Shrinkage[1] in cross section during treatment—										
Douglas fir	.13	......	.83	......	3.34	......	.73	......	9.33	......
Longleaf pine	.42	......	......	......	.08	......	......	......	.66	......
Shortleaf pine	.33	......	.50	......	.92	......	[2] .25	......	.75	......
During treatment and seasoning—										
Douglas fir	......	8.58	......	8.35	......	7.39	......	7.46	......	11.31
Longleaf pine	......	10.64	......	......	......	6.18	......	......	......	7.90
Shortleaf pine	......	10.47	......	9.30	......	5.94	......	7.50	......	5.73

[1] Shrinkage given in per cents of areas when first measured. Corresponding shrinkage of untreated material: Douglas fir, 6.40; longleaf pine, 8.48; shortleaf pine, 7.29.

[2] Increase in volume.

The shrinkage measurements on the steamed material with and without vacuum showed less than 1 per cent decrease in volume during treatment for all the species. After seasoning a shrinkage of from 8.4 per cent for Douglas fir to 10.6 per cent for longleaf pine was recorded. Steaming and vacuum followed by creosote showed a somewhat higher shrinkage for Douglas fir than for the pines, both in the unseasoned and air-dry pieces. The creasote bath had little influence on the shrinkage, the reduction after seasoning corresponding closely to the shrinkage of untreated pieces. The pressure treatment following the creosote bath showed a somewhat higher shrinkage for Douglas fir than for longleaf or shortleaf.

While the weakening in the Douglas fir stringers is not explained by the series of special tests, they indicate that the trouble has to do with stresses in the full-sized stringers, probably caused by rapid and unequal shrinkage during the process. A further series of tests is now under way on 8-foot stringers 8 by 16 inches in section treated at the Forest Products Laboratory, from which results that bear more directly on the problem are expected.

DEDUCTIONS.

(1) Timber may be very materially weakened by preservative processes.

(2) Creosote in itself aoes not appear to weaken timber.

(3) A preservative process which will seriously injure one timber may have little or no effect on the strength of another.

(4) A comparison of the effect of a preservative process on the strength of different species should not be made, unless it is the common or best adapted process for all the species compared.

(5) The same treatment given to a timber of a particular species may have a different effect upon different pieces of that species, depending upon the form of the timber used, its size, and its condition when treated.

PUBLICATIONS RELATING TO STRENGTH TESTS OF VARIOUS WOODS.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

Fire-killed Douglas Fir: A Study of Its Rate of Deterioration, Usability, and Strength. By Joseph Burke Knapp. Pp. 18, figs. 5. 1912. (Forest Service Bulletin 112.)

Mechanical Properties of Western Larch. By O. P. M. Goss. Pp. 45, Pls. IV, figs 14. 1913. (Forest Service Bulletin 122.)

Experiments on the Strength of Treated Timber. By W. Kendrick Hatt, Ph. D. Pp. 31, figs. 2, tables 12. 1906. (Forest Service Circular 39.)

Tests of Rocky Mountain Wood for Telephone Poles. By Norman de W. Betts and A. L. Heim. Pp. 28, figs. 6, tables 7. 1914. (Department Bulletin 67.)

Rocky Mountain Mine Timbers. By Norman de W. Betts. Pp. 34, figs. 7, tables 16. 1914. (Department Bulletin 77.)

Tests of Wooden Barrels. By J. A. Newlin. Pp. 12, figs. 1, Pls. V, tables 6. 1914. (Department Bulletin 86.)

PUBLICATIONS FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS.

Timber: An Elementary Discussion of the Characteristics and Properties of Wood. By Filbert Roth and B. E. Fernow. Pp. 88, figs. 49. 1895. (Forest Service Bulletin 10.) Price, 10 cents.

Effect of Moisture upon the Strength and Stiffness of Wood. By Harry Donald Tiemann, M. E. M. F. Pp. 144, figs. 25, Pls. IV. 1906. (Forest Service Bulletin 70.) Price 15 cents.

Properties and Uses of Douglas Fir: Part I, Mechanical Properties. Part II, Commercial Uses. By McGarvey Cline and J. B. Knapp. Pp. 75, Pls. III, diagrams 15. 1911. (Forest Service Bulletin 88.) Price 15 cents.

Tests of Structural Timbers. By McGarvey Cline and A. L. Heim. Pp. 123, Pls. VII, text figures 29. 1912. (Forest Service Bulletin 108.) Price 20 cents.

Mechanical Properties of Western Hemlock. By O. P. M. Goss. Pp. 45, figs. 13, Pls. VI. 1913. (Forest Service Bulletin 115.) Price 15 cents.

Holding Force of Railroad Spikes in Wooden Ties. By W. Kendrick Hatt, Ph. D. Pp. 5, figs. 4. 1906. (Forest Service Circular 46.) Price 5 cents.

Tests of Vehicle and Implement Woods. By H. B. Holroyd and H. S. Betts. Pp. 29, tables 8. 1908. (Forest Service Circular 142.) Price 5 cents.

Properties and Uses of the Southern Pines. By H. S. Betts. Pp. 30, figs. 6, 1909. (Forest Service Circular 164.) Price 5 cents.

Utilization of California Eucalypts. By H. S. Betts and C. Stowell Smith. Pp. 30, figs. 7. 1910. (Forest Service Circular 179.) Price 5 cents.

Strength Values for Structural Timbers. By McGarvey Cline. Pp. 8, tables 4. 1912. (Forest Service Circular 189.) Price 5 cents.

Mechanical Properties of Redwood. By A. L. Heim. Pp. 32, figs. 8, tables 7. 1912. (Forest Service Circular 193.) Price 5 cents.

Mechanical Properties of Woods Grown in the United States. Pp. 4, table 1. 1913. (Forest Service Circular 213.) Price 5 cents.

Tests of Packing Boxes of Various Forms. By John A. Newlin. Pp. 23, figs. 4, tables 6. 1913. (Forest Service Circular 214.) Price 5 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 287

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER September 14, 1915

A DEVICE FOR SAMPLING GRAIN, SEEDS, AND OTHER MATERIAL.

By E. G. Boerner, *Assistant in Grain Standardization.*

INTRODUCTION.

The device described in this bulletin was developed primarily to meet the demands of grain and seed dealers and laboratory workers for securing a reliable sample of grain or seed from a larger portion of the material to be examined, graded, or analyzed. It can also be used for sampling flour, meal, feeds, coal, ore, or any other material of like kind for examination or analysis and to mix or blend and divide two or more streams of unlike material of the kind specified, so that the two resulting streams will be a thorough mixture of the original two or more kinds of material.

Another application of the device which should be of special interest to the grain trade is that a sample can be divided so that one half can be used for testing and grading and the duplicate half either turned over to the seller or to the buyer of the grain or retained for future reference.

Both the construction and the process have been made simple, so that reliable samples can be obtained by any careful worker.

The operation of the device does not require power of any kind, gravity being all that is necessary to make the material pass through it.

DESCRIPTION OF THE SAMPLING DEVICE.

As is shown in figure 1, the device consists of a hopper (*A*), held in position over a cone (*D*), which is provided at its base (*G*) with a series of separated ducts (*F*) having uniform distances or spaces between them (*E*). These ducts are so constructed that they are equal to the width of the spaces between the ducts, as shown in figures 2 and 3. The ducts may be so constructed as to form an integral part of the cone or they may be adjusted to the cone by clamps, rivets, or other satisfactory means. Adjusted to the bottom of the ducts, at *H*, is a funnel (*I*) having a spout (*K*) at its bottom part, as seen in figure 1.

The ducts constitute a passageway from the exterior of the cone to the interior of the funnel, as is shown by the arrows (*M, M*) pointing downward in figure 1. Inclosing this inner funnel is another or outside funnel (*J*), also having a spout (*L*) at its base. The upper portion of the outside funnel extends over the ducts and the base of the cone, so that the enlarged opening of this outside funnel partly

Note.—This bulletin is of interest to all who have occasion to get samples of grain and seeds.

1931°—15

circumscribes the cone. As is seen in figure 4, the outside funnel is provided with an aperture (*O*) near its lower end, through which the spout (*K*) from the interior funnel passes. The space between the two funnels directly over the spout from the inside funnel is bridged with an inverted V-shaped bridge (*P*) in order to prevent the lodging of material as it passes through the apparatus.

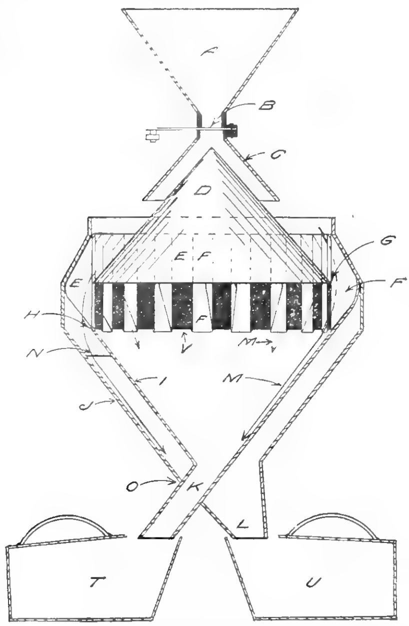

FIG. 1.—A vertical cross section of the sampling device, showing the paths taken by the material in passing from the hopper (*A*) to the receptacles (*T* and *U*).

The outside funnel may be secured to the upper and outside part of the ducts by soldering or riveting, or by any other suitable or convenient means. The outside funnel is a sufficient distance from the inside funnel to allow the material to be sampled to pass freely through the space between the two funnels. The spaces *E* between the ducts at the base of the cone constitute unobstructed passageways from the surface of the cone to the interior of the outside funnel, as is shown by the arrow *N* pointing downward in figure 1. The spaces between the ducts below the base of the cone are closed, so as to prevent any of the material which passes between the two ducts from bounding into the inner funnel as it passes through the device. This is shown by *V* in figures 1 and 2.

As seen in figure 4, the device is held in a fixed operative position by means of three supports or legs *Q*, which may rest upon any solid base. The supports are fastened to the outside funnel at two points. They should be so placed that one of them will rest on the floor at a point halfway between the two receptacles, as is shown in figure 5. The hopper at the top of the device is held in position by three supports *R*, which are soldered or riveted to the hopper and bolted to the inside rim of the outside funnel along its upper edge, each support being fastened at a point *S* opposite to the upper part of the three lower supports or legs. The hopper is so placed that the peak of the cone is directly under the center of the opening at the bottom part of the hopper, so that the material in passing through the device will spread evenly on all sides of the cone.

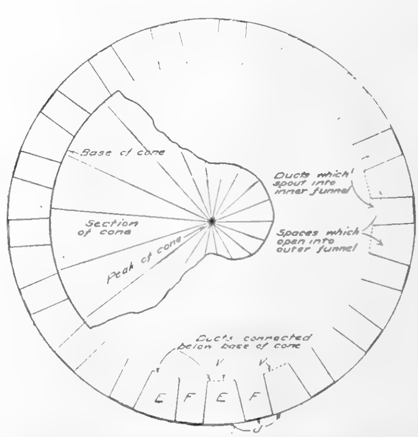

FIG. 2.—Cross section of the sampling device at the base of the cone.

In the opening at the bottom of the hopper the diameter of the short spout directly under the valve (*B*, fig. 1) is slightly larger than the diameter just above the valve, so as to prevent small seeds, dirt, etc., from being forced into the slot in which the valve fits when it is closed. Fastened to the short spout at the lower part of the hopper is a shield (*C*, fig. 1), which extends part way down over the cone. This shield prevents the material from bounding out of the apparatus as it falls on the cone from the hopper.

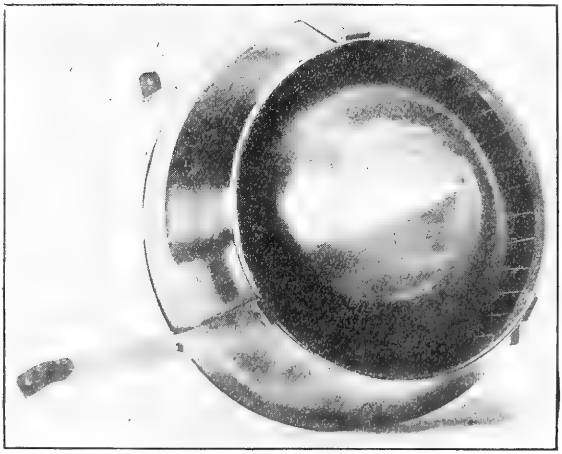

FIG. 3.—Top view of the sampling device with the hopper removed, showing the upper part of the ducts around the base of the cone.

The apparatus described may be constructed from any material which is sufficiently strong and durable to withstand the strain of the operation to which it may be subjected in effecting the sampling, mixing, or blending of the material specified. When used for grain, seeds, or ground material, it can be made of brass or a good grade of zinc, both of which metals are fairly rust resistant.

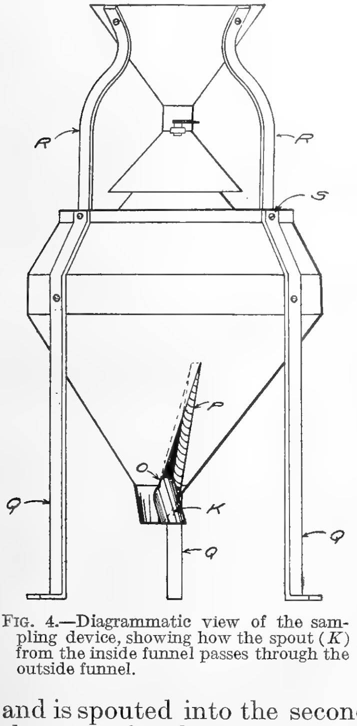

FIG. 4.—Diagrammatic view of the sampling device, showing how the spout (*K*) from the inside funnel passes through the outside funnel.

OPERATION OF THE SAMPLING DEVICE.

Place the material to be separated in the hopper and open the valve or gate, which allows the material to fall on the peak of the cone in the form of a circular column. The material then spreads on the cone into a line the length of the circumference of the cone at its base, where it is divided into sections by the ducts and the spaces. The material entering the ducts passes through them and falls into the inner funnel and finds an exit through the spout at its bottom, falling into the receptacle (*T*, fig. 1), which is placed underneath the spout for receiving the material.

All of the material which enters the spaces between the ducts at the base of the cone falls into the outer funnel and is spouted into the second container (*U*), which is placed below the spout for that purpose. A top-surface view of the receptacles is shown in figure 6.

As the widths of the ducts are equal to the widths of the spaces between the ducts, it follows that the material falling on the cone is separated into approximately equal parts, one-half passing through the spaces and the other half passing through the ducts. All of the material which falls into the spaces is spouted into one of the receptacles, while all of the material which falls into the ducts is spouted into the second receptacle.

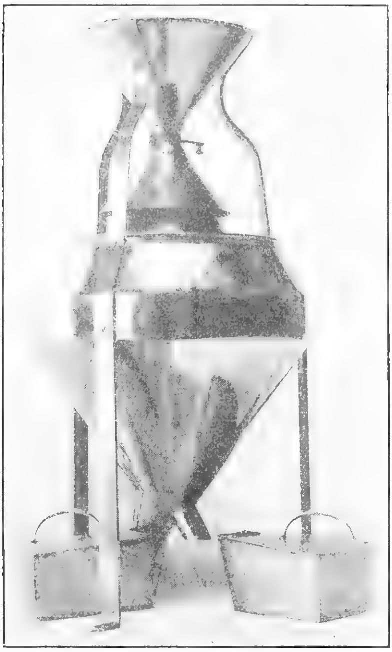

FIG. 5.—Side view of the sampling device, showing one leg placed on the left side halfway between the two receptacles.

If it is desired to obtain a smaller part of the original amount of material than one-half, it is only necessary to return to the hopper the material which falls into either of the receptacles and run such material through the device again, repeating such action as often as it may be necessary to procure a sample sufficiently small for the purpose desired; or the same result may be obtained by building up a series of superimposed devices of the kind described, so that the lower device will receive only the material which is spouted from one of the funnels.

If it is desired to obtain a small sample from a very large quantity of material, as, for instance, from either a carload or cargo of grain, as the grain is being loaded into or discharged from a car or vessel, then the construction of the device can be altered by widening the space between the ducts so that any fraction of the material entering the hopper can be made to pass into the ducts and inner funnel, and by superimposing two or more devices, one above the other, the portion taken out by the ducts in each device will reduce the original material very rapidly to a sample of any size required.

The device can also be used for blending two or more streams of wheat or other grain going to the rolls of a mill or mills. If it is used to blend two or more streams of (say) wheat of different varieties or grades, it is only necessary to spout each stream into the hopper and to bring the two resulting streams together again before the mixture enters the rolls of the mill. To supply two sets of rolls with the same blend, each stream as it leaves the device should be run to a separate set of rolls. If it is desired to run the blend to four sets of rolls, then it would be necessary to place another device under each spout of the upper device and run the grain from each of the four resulting streams to a separate set of rolls.

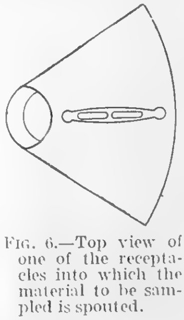

FIG. 6.—Top view of one of the receptacles into which the material to be sampled is spouted.

NOTE.—Application has been made for a patent covering this device; if patent is allowed it will be donated to the people of the United States.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 288

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ September 7, 1915

CUSTOM GINNING AS A FACTOR IN COTTON-SEED DETERIORATION.

By D. A. Saunders, *Plant Breeder*, and P. V. Cardon, *Assistant Agronomist, Office of Crop Acclimatization.*

INTRODUCTION.

The admixture of cotton seed is largely responsible for the rapid deterioration of cotton varieties which is so apparent throughout the cotton belt, and which, to a large extent, is directly traceable to the planting of seed which has been mixed at the custom gins. When plants of different varieties of cotton grow in close proximity, cross-fertilization takes place through the aid of insects and other pollen-bearing agencies, with the result that varieties become interbred and deterioration follows. Hitherto, however, nothing has been published which fully emphasizes the extent of the mixing which occurs during the ginning process, and consequently the seriousness of the evil is not generally appreciated.

The lack of definite information on this point is due, no doubt, to the difficulty in making accurate determinations of the actual amounts of seed of different varieties present in the admixture under observation. This difficulty arises from the fact that the seeds of most of the more common varieties are so similar in appearance that it is almost impossible to distinguish between them. To overcome this difficulty and to measure the degree of mixture with reasonable accuracy a method was devised by one of the writers, Mr. Saunders, at Greenville, Tex., in 1914. The results obtained from an application of this method show that mixing occurs to a far greater extent than is commonly supposed, and emphasize the necessity of materially modifying common ginning methods if supplies of pure seed are to be maintained. Full appreciation of these facts

Note.—This bulletin should be of service to all who are interested in the production and maintenance of pure cotton seed.

should prompt individuals and communities interested in keeping their cotton seed pure to bring about some form of cooperation with ginners to effectively provide against the admixture of varieties at the gin.

THE POSSIBILITY OF MIXING SEED.

The matter of preserving the purity of cotton varieties has not been given attention in the designing of ginning machinery, and the different machines and their accessories are installed without reference to the amount of seed mixing likely to occur. Since either the quantity of seed cotton ginned or the output of baled lint governs the profits of the ginner, he usually operates his plant from the standpoint of output alone, the seed question being purely secondary with him. Consequently there are several stages in the ginning process where mixing occurs unless certain precautions are exercised.

The methods generally employed in the operation of custom gins are about as follows:

A patron's seed cotton is taken up from his wagon by suction and is conveyed by the same force through flues to the battery of gins. The manner in which the seed cotton is distributed to the different gins, usually two to four in number, and the condition in which it enters them vary somewhat with the type of ginning outfit used. Usually, however, the distribution is preceded by a certain amount of mechanical beating and pulling, the purpose of which is to clean the seed cotton as much as possible and properly condition it for the actual ginning operation.

The seed cotton enters each gin through a kind of box called the feed box, or feeder. The space between the feeder and the saws, where the actual separation of lint and seeds takes place, is inclosed by a concave metal surface, and this inclosure is called the roll box.

Upon entering the roll box the seed cotton falls upon the ribs of the gin breast. Here the saws, one of which protrudes between each pair of ribs, catch the lint in their rapid, revolving motion, pull it from the seeds, and carry it on their teeth to the brushes, which in turn take it off the saws and pass it into the lint flues, through which it is conveyed by suction to the press. The seeds, being unable to pass between the ribs with the lint, fall back and are diverted by means of an inclosed metal apron into the seed conveyor. This conveyor, which usually consists of a screw or a belt in a groove or trough arranged directly under the gins, takes the seed either to hoppers, from which it may be dumped into the patron's wagon, or to the seed house, from which it will later be shipped to the oil mill.

As the saws tear through the seed cotton first fed into the roll box they give to the mass a rotary motion. This revolving mass soon assumes the shape of a roll, which gives rise to the name "roll box."

Gradually most of the lint in the roll is removed, and it becomes more truly a roll of seed. The regulated supply of seed cotton subsequently fed into the roll box revolves upon the roll, the lint is caught by the saws and carried away, and the seeds remain as part of the roll or drop out into the conveyor. Thus, there is a constant exchange of seed in the roll.

Once formed, the roll is seldom removed, but usually is allowed to remain through long periods of ginning. The ginner ordinarily tries to avoid having the roll run out or dropped, which would necessitate the formation of a new one when the next lot of cotton is fed to the gin. Sometimes the gins are stopped just before the last seed cotton of a patron passes out of the feeders, and the amount remaining is ginned as the first part of the next patron's cotton. Usually, however, the gin is run several minutes after the last of a patron's cotton leaves his wagon, in order to empty the feed boxes and practically free all of the seed in the roll box from lint before the next lot of cotton enters.

This brief description is sufficient to make clear the fact that where different varieties are ginned consecutively in the same gins mixing is inevitable unless precaution is exercised. Though the flues which convey the seed cotton are constructed with a view to facilitating the free and rapid movement of the mass, there are usually a few places where a small quantity of seed cotton may catch and remain to be collected by the passing bulk of the next lot. The amount of mixing at this juncture, however, is very slight. Mixing occurs also in the distributing, cleaning, and feeding devices, though this, too, is comparatively unimportant. The first place at which extensive mixing occurs (the place, in fact, where most of the mixing takes place) is in the roll box. Though further mixing occurs in the seed conveyor, mixing in the roll box calls for first consideration.

MIXING SEED IN THE ROLL BOX.

Seeds in the roll remaining in each roll box after the ginning of one variety gradually are replaced by seeds of the next variety as it passes through the gins. The replaced seeds are mixed with seeds of the variety being ginned, and together they drop into the conveyor and thence into the patron's wagon. The amount of mixing which occurs in the roll box clearly depends upon the rapidity with which the exchange of seeds takes place. As a means of determining the rapidity of exchange and the consequent amount of mixing, the method here described was employed: [1]

The seed roll was removed from a 70-saw gin and the seeds were stained red with ordinary dye in order to mark them distinctively. Then they were thoroughly sun-dried and finally returned to the roll box. The roll was packed as near as possible to the density it had before being removed. When the next bale was ginned, samples of the seed were taken every five minutes from the gin containing the colored roll as the seed dropped into the conveyor. The proportion of red seeds in each sample was then determined. The results of these determinations are given in Table I. (See also figs. 1 to 5.)

TABLE I.—*Extent of mixture in samples of cotton seed taken from the roll of a single gin stand in a battery of three stands at intervals of 5 minutes, as determined at Greenville, Tex., Sept. 7, 1914.*

Time of sampling after ginning had begun.	Number and character of seeds in each sample.			Red seed.
	Total.	White.	Red.	
				Per cent.
5 minutes	521	250	271	52.0
10 minutes	478	396	82	17.1
15 minutes	527	488	39	7.4
20 minutes	835	812	23	2.8
25 minutes	603	600	3	.5
30 minutes	801	800	1	.1

[1] The writers wish to acknowledge the assistance rendered in this experiment by Mr. George Chandler, whose gin was used in securing the results presented herein.

For several minutes only stained seed appeared. After the gin had been running 5 minutes the sample taken showed 52 per cent of colored seed. At the end of the first 10 minutes the sample showed 17.1 per cent of stained seed and after 15 minutes 7.4 per cent, while at the end of 20 minutes 2.8 per cent of stained seed appeared

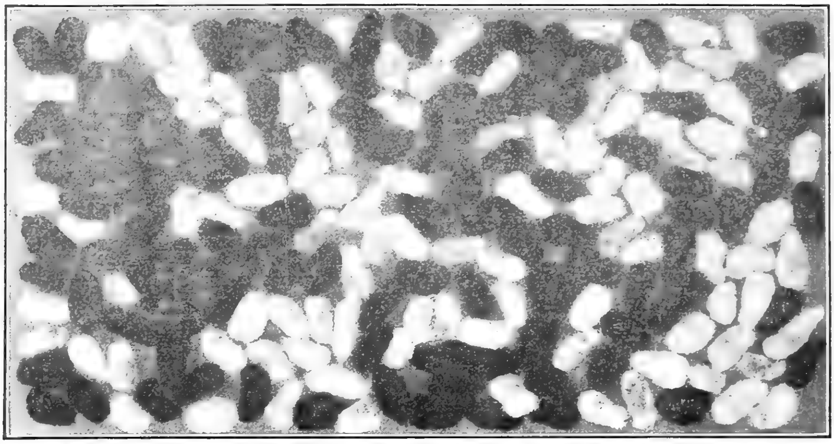

FIG. 1.—Sample of cotton seed taken 5 minutes after the ginning of the second bale had begun, showing 52 per cent of red seed from the stained roll of the first bale.

in the sample. The sample taken at the end of 25 minutes showed 0.5 per cent of stained seed, and the one taken at the 30-minute period showed 0.1 per cent, or 1 seed in a sample of 801 seeds.

When the bale was ginned, the roll was carefully examined and 32 stained seeds were found. Not until 10 minutes after the second bale had been started did these

FIG. 2.—Sample of cotton seed taken 10 minutes after the ginning of the second bale had begun, showing 17.1 per cent of red seed from the stained roll of the first bale.

pass out of the gin. No stained seeds were found in the roll box after the ginning of the second bale.

These results indicate that the exchange of seeds in the roll takes place very rapidly, practically the entire roll being replaced during the ginning of a single bale. Most of the red seeds passed out of the roll box during the first few minutes the gin was in operation. It is possible that if it had not been necessary to remove the roll

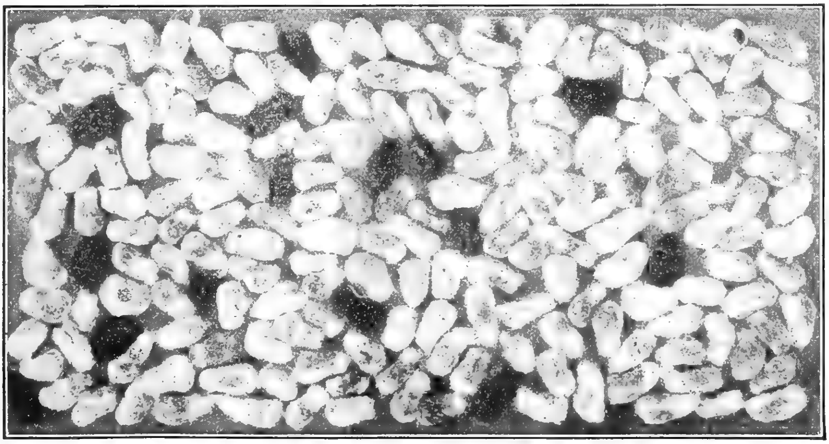

FIG. 3.—Sample of cotton seed taken 15 minutes after the ginning of the second bale had begun, showing 7.4 per cent of red seed from the stained roll of the first bale.

to stain it (that is, if a stained roll could have been formed in the normal way) mixing might have been apparent through a longer period of time; but it is reasonable to believe that the results obtained would not have been modified materially.

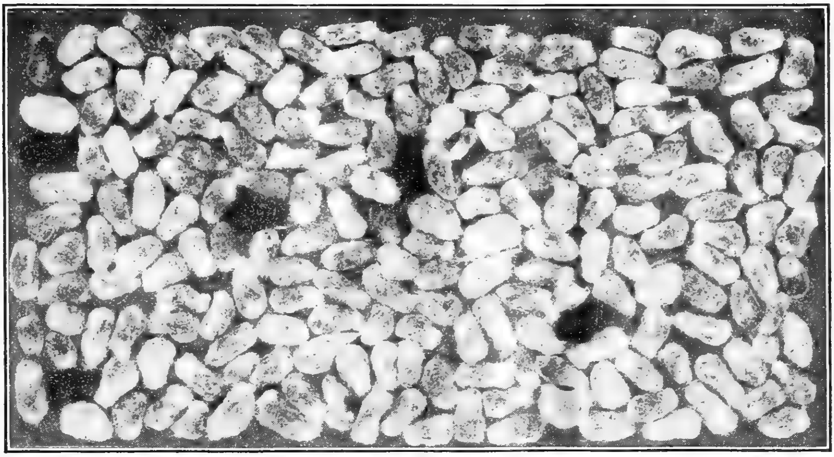

FIG. 4.—Sample of cotton seed taken 20 minutes after the ginning of the second bale had begun, showing 2.8 per cent of red seed from the stained roll of the first bale.

These results were obtained from only one gin. It is evident that in a battery of four or more gins the chance of mixing seed is greatly increased. However, taking these results as a basis, rather dependable calculations can be made for the purpose of showing in round numbers about how much mixing may occur. Each roll contains from 35 to 40 pounds of seed, or slightly more than a bushel. The four rolls in a 4-gin battery therefore would contain from 140 to 160 pounds, or from 4 to 5 bushels of seed. If most of these passed out of the roll boxes during the ginning of a bale of cotton, as is indicated by the results at hand, they would comprise from 14 to 16 per cent by weight of the total quantity (about 1,000 pounds) of seed usually obtained by the patron from the seed cotton necessary to make a bale of lint.

While such an admixture in itself is sufficient to justify a demand for more care than is ordinarily exercised at custom gins, it must be remembered that the roll box is not the only source of mixture at the gin.

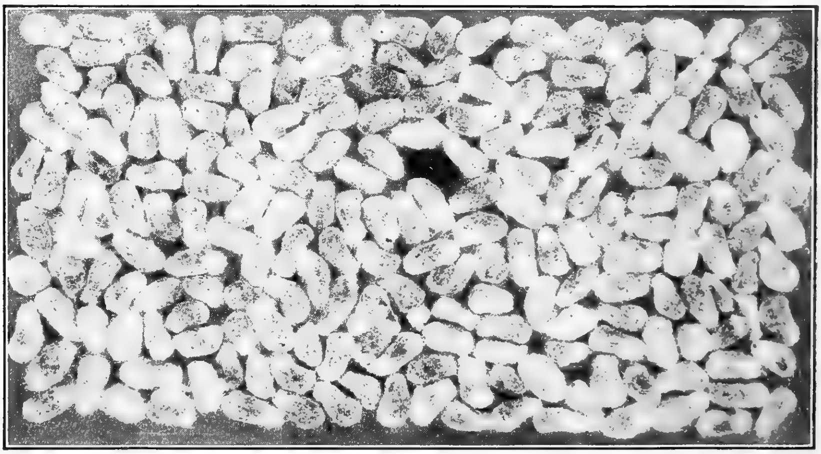

FIG. 5.—Sample of cotton seed taken 25 minutes after the ginning of the second bale had begun, showing 0.5 per cent of red seed from the stained roll of the first bale.

OTHER SOURCES OF MIXTURE.

It has already been pointed out that some mixing may occur before the seed cotton reaches the roll box, and also that further mixing occurs in the seed conveyor. While it is impossible to determine the amount of mixing which may occur in the flues, it may be measured in the seed conveyor by a continuation of the method employed in making determinations in the roll box.

Such determinations were not made at Greenville, but it was observed that even after the second bale was ginned red seeds were found scattered along the conveyor from the gin to the seed house. Thus, while the seed was badly mixed before it was delivered into the conveyor, it was mixed more and more thoroughly as it was stirred and crowded forward by the conveyor screw. For this reason it is apparent that the amount of mixture in the seed delivered to the patron is even greater than is indicated by the determinations made at the gin.

SIGNIFICANCE OF THE RESULTS OBTAINED.

Previous publications[1] of the Department of Agriculture have described methods of selecting cotton and ways of maintaining through community action the supply of pure seed. While there are already many individuals who recognize the value of pure seed and are much concerned about maintaining a permanent supply, it is likely that the movement for better cotton will develop very rapidly in the next few years. That careful methods of selection must be supplemented by careful ginning methods if the movement is to succeed is made clear by the results here discussed. Farmers must take steps to minimize mixing at custom gins if they are to maintain the purity of their improved varieties and in this way prevent deterioration.

It has been shown that no less than 14 to 16 per cent, and probably much more, of the seed delivered to a patron at custom gins as ordinarily operated is seed of the variety ginned just previous to the arrival of his cotton. The results at Greenville indicate also that some seeds from the second bale preceding are likely to appear in the seed delivered to the patron. This means that if different varieties are being ginned consecutively a patron will receive in the seed delivered to him at the gin an admixture of at least three varieties. It is apparent that if such seed is planted opportunity is afforded for a vast amount of cross-fertilization in the field, and deterioration begins. During the next ginning process one or more other varieties may be added to the mixture and still further opportunity for crossing is afforded. Thus, a farmer may start out with an improved variety and in a few years find that his crop ceases to show marks of improvement and more nearly represents a composite stock of many varieties. Deterioration has developed so far that the bolls are small, the yield is light, the plants are not storm-proof, and the fiber produced is of poor quality and brings only low prices.

WAYS OF MINIMIZING THE AMOUNT OF MIXING.

It should be possible for interested patrons to establish some understanding with the ginner whereby he will cooperate in taking precautions aimed at minimizing the amount of mixing likely to occur. The precautions which appear most practicable and which even now are exercised in some localities involve the following steps:

The patron should accompany to the gin the lot of seed cotton from which he expects to save seed for planting, and he should aid the ginner in seeing that everything possible is done to prevent mixing.

He should see that the flues, feeders, and cleaners are cleaned as thoroughly as their construction will permit before he allows his seed cotton to enter them.

The roll should be dropped from the roll box and the box should be thoroughly cleaned. The dropping of the roll is an operation with which all ginners are familiar.

[1] Cook, O. F. Cotton selection on the farm by the characters of the stalks, leaves, and bolls. U. S. Dept. Agr., Bur. Plant Indus. Circ. 66, 23 p., 1910.

——— Cotton improvement on a community basis. U. S. Dept. Agr. Yearbook, 1911, p. 397–410. 1911.

The construction of the gins is such that the roll can be dropped and the box cleaned in a very few minutes. Some improved gins are arranged so that the roll box may be emptied without stopping the gin, thereby further simplifying the operation.

Having cleaned the machinery up to and including the roll box, the next step is to prevent the seed of the variety to be ginned from falling into the conveyor. It is impracticable to clean the conveyor satisfactorily, and therefore it should not be used when planting seed is to be obtained. By adjusting the position of the apron of each gin the seed can be made to fall upon the floor in front of the gin instead of into the conveyor. From here it can be sacked easily.

The floors about the gins should be cleaned to the extent that no seeds are left lying around to cause mixing. Canvas spread upon the floor to receive the seed from the gins is often used.

Such precautions require time in which to carry them out effectively, and time spent in this manner naturally reduces somewhat the amount of ginning that otherwise could be done in a day. On this point the ginner may find cause to base objection to such procedure, but it should be possible to meet the objection by fully compensating him for the extra time consumed. The expense of special ginning in some sections may be reduced by arranging to have it done on specified days or at the close of the season, when more time is available. In any event, the amount of money that may be required to secure the ginner's cooperation in the maintenance of pure seed is almost negligible in view of the favorable effect such precautions will have upon the farmer's crops in succeeding years.

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WM. A. TAYLOR, Chief

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RED-CLOVER SEED PRODUCTION: POLLINATION STUDIES.

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CONTENTS.

INTRODUCTION.

For a number of years the quantity of seed of red clover (*Trifolium pratense*) produced in this country has been insufficient to supply the demand for reseeding purposes in the clover-belt States. This not only has caused the seed to be high in price, but has resulted in the importation of large quantities of foreign seed, some of which, on account of the impurities present and its low vitality, has been considerably less desirable than the ordinary home-grown strains.

The prime importance of clover in the ordinary farm rotations in the corn and clover belt States makes the continued maintenance of the clover acreage of great moment to the agricultural prosperity of the country. This problem has been approached from four different angles. First, to determine the minimum amount of seed necessary to obtain a stand, so that much less than the quantity of seed ordinarily sown will be sufficient to produce a satisfactory yield, for any reduction in the quantity of seed required to sow an acre will proportionately increase the acreage throughout the country which can be sown with the available supply of seed. The second line of attack has been to determine the environmental conditions necessary to the maintenance of a satisfactory stand of clover. That these conditions are less favorable than they have been in the past is indicated by the increasing difficulty experienced by many farmers in maintaining clover in the ordinary rotations. A third line of attack has been the possibility of developing a heavy-seeding, hardy strain of clover with good forage and hay producing qualities. The fourth line of attack, the one with which the present publication is concerned, has been a study of various means of affecting the yield of clover seed under field conditions as they exist throughout the clover-growing sections of the country. One phase of this work has been to determine the effect of the time of cutting or clipping the first growth on the seed production of the subsequent crop. The second phase, that with which this bulletin is primarily concerned, has been the effect of various mechanical forms of pollination upon the quantity of seed produced.

PREVIOUS INVESTIGATIONS ON THE POLLINATION OF RED CLOVER.

Since the time of the publication of the statement by Darwin (6, p. 361; 7, p. 90)[1] that 100 heads of red clover on plants protected from insects during the blooming period did not produce a single seed while a similar number of heads exposed to insects produced an average of 27 seeds per head, many scientists have investigated this subject. Knuth (22, v. 1, p. 36–37; v. 2, p. 289) accepts Darwin's experimental results and states that red clover, crimson clover, and white clover are among the best examples of self-sterility in plants. Stebler and Schröter (39, p. 123) in discussing the pollination of red clover say that there is no experimental evidence to show that pollen from a flower can not, when applied to its own stigma, fertilize the ovules, but they also state that pollen which is effective in producing fertilization has in all probability come from some other flower. The same authors (40, p. 14, 122) in a later edition state that red clover is self-sterile. Frandsen, according to Lindhard (23), found red clover to be practically self-sterile. From 1,235 flowers in 1910 and 1,305 flowers in 1911, which were self-pollinated by Frandsen, 0.07 per cent set seed. In 1910 Frandsen pollinated 1,488 flowers and in 1911, 1,455 flowers with pollen from other heads on the same plants; 0.8 per cent of the flowers set seed in 1910 and 0.4 per cent in 1911.

Wallace (43, p. 121) states that insects must perform the indispensable work of cross-pollinating red clover, but later says (44) that he has been inclined to think that climatic conditions rather than the

[1] Reference is made by number to "Literature cited," p. 29.

presence or absence of insects influence seed production. The work of Sirrine (37, p. 89–90), as well as that of Witte (46), showed red clover to be self-sterile. In the experiments of Cook (5), Shamel (36), and Kirchner (21) no seed was produced when heads were covered before blooming and not pollinated. Fruwirth (11; 12, p. 163–166) did not obtain a single seed when heads under cover were left undisturbed or when they were pollinated with pollen from another head on the same plant, while heads pollinated with pollen from another plant produced seed. Bolley (4) obtained but two seeds from one head of a large area which was placed under a fine screen before any of the flowers came into bloom. He states that insects other than bumblebees must pollinate the flowers, since the bumblebees were scarce and the clover set well. Genevier (13) states that the fertilization of clover does not depend on the presence of bumblebees. Pammel and King (32) report but two seeds from 643 heads which were allowed to mature under a screen cover, while Washburn (45) says that only by the aid of bumblebees was he able to obtain seed.

Armstrong (1), in writing about New Zealand, says there is every reason to believe that numerous individuals belonging to *Trifolium pratense* are self-fertile and that they produce self-fertile progeny. According to him the American strain is usually, if not always, self-fertile. McAlpine (24) discusses Garton's experiments, which show that the self-fertilizing property is as common with red clover as it is with the bean. The following is quoted from Kerner (20, p. 407): "Pisum and Ervum, Lotus and Melilotus, the various species of Trifolium, almost all of them, when unvisited by insects, ripen seed, only a few species here and there being infertile when dependent upon their own resources." Nothing definite can be taken from Kerner's statement, since he does not quote any species or give definite exceptions to his statement. Hopkins (14) says he is not ready to admit that self-fertilization does not take place and that he is inclined to believe a crop of seed can be grown without the aid of bumblebees. The same author (15, p. 73) states that honeybees serve the same purpose as bumblebees in cross-fertilizing red clover. The work of Beal (2, p. 325–328) shows that bumblebees increased the seed production about four times, since in a check cage he received 25 seeds from 50 heads, while in the cage where bumblebees were placed 94 seeds from 50 heads were obtained. Martinet (27) found red clover to be self-fertile, stating that cross-pollination might have been brought about by very small insects (undoubtedly meaning thrips). Fruwirth (12, p. 163–166), however, showed that thrips transferred from other clover fields in large numbers produced no seed in his experiments. Meehan (28) states that a careful examination of the clover flower in all its stages convinced him that from its structure and behavior it was self-fertile. It is still an open question whether or not red clover is self-fertile, according to Smith (38, p. 236).

Garton, according to Wallace (44), claims that red-clover flowers are cleistogamous, but Martin (26) in his work on the cytology of red-clover flowers disproved this theory. Garton attempts to prove that the flowers are cleistogamous by saying that the ovules are well formed by the time the flowers open. The ovary is quite large at this time, and it was undoubtedly taken to be a developing ovule. Pammel and King (32) record that self-fertilization was accomplished in some experiments at Ames, Iowa, by irritating the stigmas. Hunt (19) speaks as follows: "It has long been recognized that red-clover and other leguminous flowers may be self-pollinated, although it has never been determined whether self-pollination or cross-pollination most commonly occurs."

According to Dunning (8), after the introduction and establishment of bumblebees in New Zealand red clover seeded abundantly, but previous to this time he says it seeded very little. The Agricultural Gazette of New South Wales (9, 16) maintains that bumblebees were introduced into New South Wales from New Zealand so that they would be able to produce clover seed for home use, which up to this time was largely imported. At Failford, New South Wales, red clover seeded abundantly (35), although no bumblebees had been noticed in that vicinity. The pollinating was thought to have been done by several native insects. This was several years after the introduction of bumblebees. Later (17) it was stated that bumblebees had become well established.

Waldron (41, 42) found in his experiments that bumblebees were responsible for about 95 per cent of red-clover seed and that a small quantity may be produced by natural self-pollination.

Müller (29, p. 184–186) states that when a bee draws its proboscis out of a clover flower cross-pollination is assured and self-pollination may also take place, but that the self-pollination is probably neutralized and superseded by the immediately preceding cross-pollination.

Folsom (10, p. 116) considers the Italian race of honeybees as important as the bumblebees in clover-seed production, while Armstrong (1) claims that honeybees are able to extract nectar from red-clover flowers in New Zealand. Pammel (31, p. 172) shows that honeybees are able to collect pollen from red-clover flowers and thereby cross-pollinate them. Robertson (33, p. 177) states as follows: "But while butterflies may sometimes effect cross-fertilization of the red clover, they are of doubtful value, if not injurious. * * * But butterflies can insert their thin tongues without depressing the keel, and, even if they get a little pollen on their thin proboscides, it is apt to be wiped off by the closely approximated tips of the petals, which close the mouths of the flowers."

OUTLINE OF POLLINATING EXPERIMENTS.

It is a well-known fact that the yield of clover seed varies greatly from year to year, and no distinct correlation with any marked climatic factors has been determined. It was thought that possibly the absence of suitable pollinating insects, such as bumblebees, might in some seasons be responsible for the reduced yields of seeds. This is especially true when conditions were such that there was no other apparent reason for the failure of the crop to set seed. In order to obtain light on this point, a series of experiments was outlined to determine (1) whether clover flowers were able to set seed without the assistance of outside agencies; (2) whether clover flowers were able to set seed when their own pollen was transferred to their stigmas by outside agencies; and (3) the relative efficiency of the honeybee and the bumblebee as cross-pollinators of red clover.

In order to overcome any local environmental factors, the experiments were conducted at Ames, Iowa, and La Fayette, Ind., and were repeated to some extent at the Arlington Experiment Farm, Va. The work on individual clover heads was performed on heads protected from the action of insects by tarlatan cloth. This cloth has about twice as many meshes to the linear inch as ordinary mosquito netting. Where numerous plants were to be protected from all outside agencies, cages of wire screen having 14 meshes to the linear inch were used. In some instances, where it was desired to permit the entrance of all insects smaller than bumblebees, cages made of galvanized-wire screen having four meshes to the linear inch were employed.

All work was done on second-crop red clover unless otherwise specifically stated.

STRUCTURE OF THE RED-CLOVER FLOWER.

The heads of red clover contain from 35 to 150 flowers each, and according to Pammel and Clark (30) the average number per head for black loam soil at Ames, Iowa, is 71.1 for the first crop and 98.1 for the second crop

The flowers of red clover consist of a green pubescent calyx with five pointed lobes and an irregular magenta or purple corolla of five petals (Fig 1.) The claws of the petals are more or less united to the staminal tube This staminal tube is formed by the union of the filaments of the nine inferior stamens To the greater portion of the anterior end of this common tube, formed by the uniting of the claws of the petals with the staminal tube, is attached the broad base of the vexillum. The carina, which is composed of two petals united at one edge, is attached to the inferior part of the edge of the tube not occupied by the vexillum. Even though the base of the carina is narrow it is able to return to its normal position shortly after being bent downward. The alæ are attached by their flexible claws to the common tube. Before a flower opens the alæ are pressed closely to the carina, although as the flower matures they spread apart. The staminal tube splits superiorly to admit the tenth free stamen. The filament of this superior stamen lies along the side of the staminal tube and therefore does not interfere with the proboscis of a bee which is inserted to collect nectar. Nectar is secreted at the bases of the stamens and accumulates in the staminal tube around the base

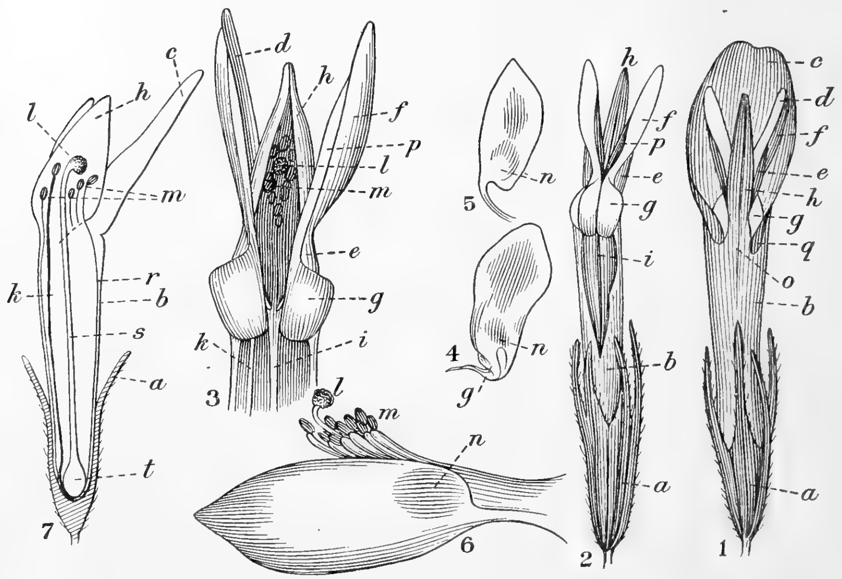

FIG. 1.—Different parts of a red-clover flower: 1, Anterior view of flower; 2, posterior view of flower after the vexillum has been removed; 3, posterior view of flower, showing the carina, which has been forced apart (twice the magnification of the other drawings); 4, right ala, from within; 5, right half of carina, from without, the claws of 4 and 5 having been partly broken off; 6, the essential organs emerging from the depressed carina; 7, longitudinal section of a flower. *a*, Calyx; *b*, tube formed by the partial union of 9 filaments with the claws of the vexillum, alæ, and carina; *c*, vexillum; *d*, concave part of the inner side of ala; *e*, lower border of ala, bent outward; *f*, outward surface of ala; *g*, pouched swelling on the base of an ala; *h*, carina; *i*, style; *k*, superior free stamen; *l*, stigma; *m*, anthers; *n*, point of union between alæ and carina; *o*, point of flexure of the carina; *p*, part of the upper border of ala, bent outward; *q* downward extension of the vexillum; *r*, staminal tube; *s*, style; *t*, ovary. (After Müller in part.)

of the ovary. The filaments which compose the staminal tube separate in the hollow of the carina. Each filament bears a fertile anther. The pistil is inclosed within the staminal tube, the upper part of the style and stigma of which are inclosed with the anthers in the carina. The stigma is situated slightly above the stamens in most flowers, although in some the anther of the longest stamen is as high as the stigma.

When a bee inserts its proboscis into the staminal tube, it is inserted between the vexillum and the carina. In doing this the carina and alæ are pressed downward and the stigma and anthers are thrust up against the bee's head. Since the carina and stamens are elastic, the pollen is thrown with considerable force against the head of the bee. When the bee releases the pressure on the carina and alæ, the parts return to their normal position on account of the elasticity of the base of the carina and a small dilated vesicular process at the base of each ala. (Fig. 1.)

LENGTH OF THE COROLLA TUBE OF RED-CLOVER FLOWERS.

The corolla tube of red clover is stated by Knuth (22, v. 2, p. 289) and Müller (29, pp. 184–186) to be from 9 to 10 millimeters in length. Pammel and King (32) report an average length of 9.4 millimeters for 450 flowers. Schachinger, according to Fruwirth (12, pp. 163–166), says the corolla tubes are shorter in the second crop than in the first crop, and for this reason smaller bees are able to work on the second crop than on the first.

Fifteen corolla tubes from each of 28 heads of first-crop red clover were measured at Ames, Iowa. The greatest variation found in different flowers of the same head was 2 millimeters. The 420 corolla tubes varied from 8.5 millimeters to 11.5 millimeters, with an average length of 9.6 millimeters.

DEVELOPMENT OF THE FLOWERS OF RED CLOVER.

The stamens of red clover develop much more rapidly than the pistil, and the length of the longer set exceeds that of the pistil until near the time the flower opens. The pollen is formed in the longer stamens through the division of the mother cells when the pistil is about 0.25 millimeter in length. The division in the pollen mother cells of the shorter stamens closely follows that in the longer stamens. When the pistil is about 1 millimeter in length, only about one-twelfth of its length at maturity (fig. 2, *A*), the pollen grains are apparently mature so far as their size, their shape, and the thickness of their walls are concerned. At this stage the two ovules are well formed, but the egg and endosperm cells are not developed till later and are not ready for fertilization until just previous to the opening of the corolla. The later development of the pollen consists in protoplasmic changes. After the pollen grains have reached their mature size and their walls have become mature the protoplasm shows very little or no granular nature. Just before the flowers open the protoplasm becomes very dense. At this stage the protoplasm contains much oil in the form of an emulsion. The pollen will now germinate.

The pistil has a stylar canal reaching from the ovary almost to the stigma. Just previous to and during the opening of the corolla the pistil elongates more rapidly than the stamens, and as a result the stigma is usually pushed beyond the anthers in the open flower (fig. 2, *B*). The stigmatic surface is papillate and has a fringed appearance in the mature flower. The papillæ contain much oil and have rather heavy walls, which react to the test for cutin.

Both ovules develop embryo sacs (fig. 2, *C*). Fertilization usually takes place in each ovule; but only one, so far as observed, matures into a seed. Should plants occur that mature both ovules, there would be an opportunity to produce strains with twice the seed-yielding capacity of those now grown.

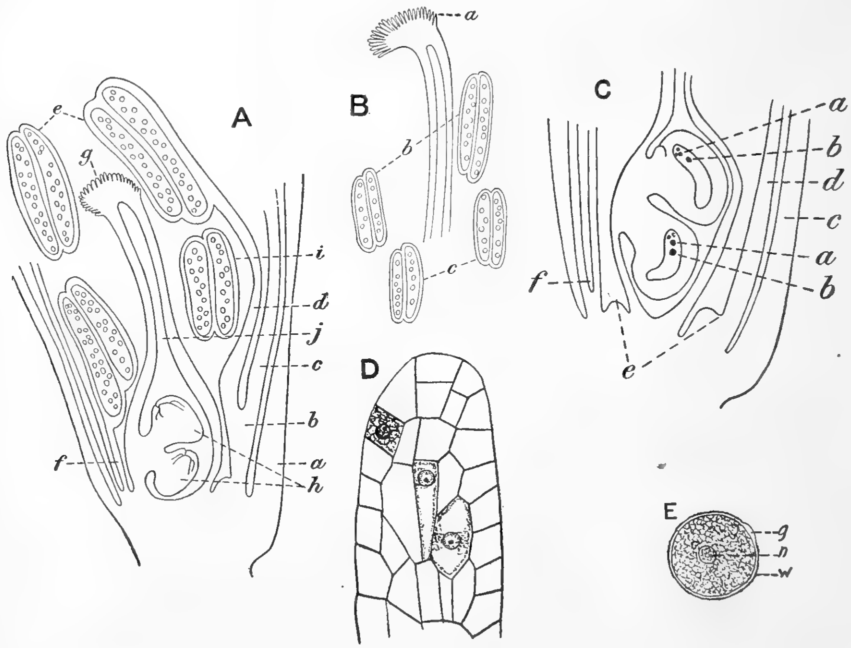

FIG. 2.—Red-clover flowers, showing different stages of development. A.—Lengthwise section of a red-clover flower at an early stage (×50): *a*, Calyx tube; *b*, staminal tube; *c*, standard; *d*, one of the long stamens; *e*, anthers of two long stamens; *f*, free stamen; *g*, stigma; *h*, the two ovules; *i*, anther of a short stamen; *j*, stylar canal. B.—Lengthwise section of an open flower, showing the character of the stigma and its position relative to the anthers (×25): *a*, Stigma; *b*, anthers of two long stamens; *c*, anthers of two short stamens. C.—Lengthwise section through the base of a flower, open and ready for fertilization (×40): *a*, Egg; *b*, endosperm cell; *c*, calyx; *d*, staminal tube; *e*, nectar glands; *f*, free stamen. D.—A median, longitudinal section through the nucellus of a sterile ovule which should have been ready for fertilization, the flower being open; all cells remained vegetative and no reproductive cells were produced (×18). E.—Pollen grain (×325): *g*, Germ pore; *n*, nucleus; *w*, wall.

INFERTILE OVULES OF RED CLOVER.

Infertile ovules are a common occurrence in red clover and occur to a considerable extent throughout the season. A section through the nucellus of an infertile ovule is shown in figure 2, *D*. In the infertile ovules all cells remain vegetative and no embryo sac is formed. The largest percentage of infertility has been found to occur in first-crop red clover, and this infertility appears to accompany moist soil and atmospheric conditions. During the first crop many plants produce

100 per cent of infertile ovules. With such plants the presence of bees is not a matter of importance, for the ovules have no reproductive cells; hence there can be no fertilization and no production of seed. During the second crop, when the season is generally dry and favorable for seed setting, there is some infertility, ranging from a low percentage or none in some plants to a high percentage in others. It is very probable that this infertility of ovules is to a greater or less degree a hereditary character and that the production of a high-yielding strain will consist, among other features, in selecting those plants with the least tendency toward infertility.

POLLEN OF RED CLOVER.

The pollen grains of red clover are almost globular when turgid, with a little flattening at the germ pores. When measured in a 25 per cent cane-sugar solution the pollen grains have an average size of 44.5 by 43 μ (fig. 2, *E*). The grains are not fully turgid when shed from the anthers and one diameter in each is shortened and the other diameter lengthened by an infolding of the wall. In this condition Martin (25) found the average dimensions of 100 pollen grains to be 26 by 48 μ, while Miss Clark (30) found the average size of 1,024 pollen grains to be 31.7 by 56.29 μ.

When dropped in water the pollen grains take it up very rapidly and burst almost instantly. On account of this feature of the pollen there can be little effective pollination when the flowers are wet. Pollination at night or in the morning when the flowers are wet with dew is not likely to be effective.

Germination of the pollen of red clover was found by Martin (25) to depend upon a proper water supply. Good artificial germination can be secured on parchment paper or animal membranes which are just moist enough to permit the pollen to absorb the requisite amount of water for germination. Germination takes place within a limited range of variation in the water supply, and it is only by trials of wetting and drying that the proper moisture content of the membranes may be secured. Under proper conditions of moisture and temperature, germination takes place usually in 8 to 10 minutes.

FUNCTION OF THE STIGMAS OF RED-CLOVER FLOWERS.

Microchemical tests of the stigmas of red-clover flowers show no sugars or starches present. An oily emulsion, however, does occur in the papillæ. Crushed stigmas placed on animal membranes had no apparent effect on the germination of the pollen or on the directions of the tubes.

When pollen is deposited on the stigmas it lodges between the papillæ, takes up water, and soon becomes turgid, but the water supply is so regulated by the stigmas that no bursting occurs. It is probable that the only function of the stigmas in the germination of the pollen is that of supplying the requisite amount of moisture to the pollen. If such is the function of the stigmas, a wet soil or humid atmosphere, both of which tend to increase the water content of the stigmas, may allow the pollen to absorb too much water and thus prevent fertilization. Martin (25) found pollen lying dormant on stigmas 18 hours after pollination during cool, moist weather. This dormancy might have been due to the effect of low temperature upon the pollen alone, but could have been due to an interference with the moisture adjustment.

FERTILIZATION OF RED-CLOVER FLOWERS.

TIME REQUIRED BETWEEN POLLINATION AND FERTILIZATION.

The time between the pollination and the fertilization of red-clover flowers varies. Flowers pollinated in July, when the temperature was high and killed 18 hours after pollination, showed that in most cases fertilization had taken place. In October, when the temperature was much lower, the time between pollination and fertilization ranged from 35 to 50 hours.

NECESSITY OF FERTILIZATION OF RED-CLOVER FLOWERS.

It has been reported that red clover is able to develop seed without fertilization; but field experiments, as well as laboratory tests, have disproved this statement. One of the most noticeable features of this work was the fact that all the flowers of heads which were covered with tarlatan before they came into bloom and left in this condition until they withered remained in full bloom from 9 to 10 days. Flowers of red clover wither shortly after fertilization takes place. This is why red clover heads usually contain flowers in bud, in bloom, and withered at the same time.

In order to further test the necessity of fertilization, a large number of heads were covered with tarlatan before any flowers came into bloom. An examination of more than 500 flowers at various times after they began to wilt showed no embryos. The ovules were disintegrating.

POTENCY OF POLLEN IN SELF-POLLINATION.

In order to determine the potency of pollen in self-pollinated flowers of red clover, a number of heads were covered with tarlatan two or three days previous to the opening of the flowers. Some of these covered flowers were self-pollinated by springing the carinas, while the rest were cross-pollinated by springing the carinas and applying pollen from flowers on other plants to their stigmas. By mounting the pistils of these flowers in a 30 per cent sucrose solution and flattening them with a little pressure on the cover glass, the pollen tubes could be traced through the stylar canals, as pollen tubes have a denser and more granular content than the cells of the style.

An examination of 30 flowers which had been self-pollinated for 55 hours showed good germination on the stigmas but no fertilization. The number of pollen grains germinating on the stigmas ranged from 3 to 25 in each of the 30 flowers. The tubes had made a slow growth and none exceeded 4 millimeters in length. An examination of 20 flowers which had been self-pollinated for 90 hours showed that one pollen tube had attained a length of 7.5 millimeters, while the others were 5 millimeters or less in length. At this rate of growth the longest tube would have required about 48 hours more to reach the ovules, or about six days to traverse the entire distance from stigma to ovule. Flowers examined four days after springing the carinas showed the eggs in a disintegrated condition. It is therefore probable that in case of self-pollination the pollen tubes do not reach the ovules in time to effect fertilization.

An examination of the 30 flowers which had been cross-pollinated for 55 hours showed that fertilization had taken place in all of them.

CROSS-POLLINATION AND SELF-POLLINATION OF RED CLOVER.

The results published by previous investigators on the cross-pollination and the self-pollination of red clover do not agree. These investigators appear to be about equally divided as to whether red-clover flowers are self-fertile or not. The experiments of Frandsen, according to Lindhard (23), Fruwirth (12, p. 163–166), and others show that red-clover heads which were covered during their blooming period and not pollinated failed to set seed Frandsen and Fruwirth also show that pollen must come from an entirely separate plant in order to fertilize the ovules of red-clover flowers. On the other hand, Garton, according to McAlpine (24) states that self-pollination is as common with red clover as it is with the bean.

The relative efficiency of the bumblebee and honeybee as cross-pollinators of red clover has also been discussed by scientific investigators, as well as by agricultural papers and bee keepers. Bee men generally agree that the Italian race of honeybees can extract nectar from red-clover flowers. Little has been said, however, about the ability of the honeybee to collect pollen from red clover.

In view of the above diverse opinions in regard to the self-pollination and the cross-pollination of red clover, a number of experiments were outlined in order to determine (1) whether red-clover flowers were self-fertile; (2) if self-fertile, whether any effective method of self-pollination could be found which would be applicable for use on a field scale; and (3) the relative efficiency of the bumblebee and honeybee as cross-pollinators of red clover.

ARTIFICIAL MANIPULATION OF CLOVER HEADS.

Experiments were conducted to determine, if possible, the effect on seed production of various types of artificial manipulation of the clover heads while the flowers were in bloom (fig. 3). A sufficient number of heads were selected on each plant so that the work could be conducted on heads covered with tarlatan (fig. 4) and on heads exposed to the action of insects. The experiments on the heads exposed to the action of insects were to determine whether the artificial manipulation of the flowers would have any harmful effect on seed production. The different treatments given the heads covered with tarlatan were to determine whether fertilization could be

FIG. 3.—A screen cage (in the background) in which bumblebees were confined. Hand-pollination work is in progress in the foreground.

produced by any method of artificially manipulating clover flowers from which insects were excluded. For this work, plants were selected bearing at least eight heads which would come into bloom at approximately the same time. These plants were taken at random and each marked with a stake, as shown in figure 5. The heads on each plant were labeled from A to H, inclusive, and treated as shown in Table I.

These experiments were conducted in Iowa, in 1911 on 50 plants at Ames, and 25 at Altoona, and in 1912 on 70 plants at Ames.

Table II gives the results obtained on 25 representative plants, selected from the entire number, and also the average seed yield per head of the entire 145 plants experimented with in 1911 and 1912.

Table I.—*Treatment of clover blossoms in the artificial manipulation experiments.*

Head.	Heads not covered with tarlatan.	Heads covered with tarlatan.
A	Check.	
B	Entire head rolled between thumb and finger.	
C	Keel of each flower sprung with a toothpick, care being taken to rub the pollen on each stigma. (A separate toothpick was used for each head.)	
D	Tapped several times with coarse toothbrush.	
E		Check.
F		Worked same as B.
G		Worked same as C.
H		Worked same as D.

Table II.—*Effect of different types of artificial manipulation upon the seed production of red-clover plants treated in 1911 and 1912.*

25 Selected Representative Plants.

Location, year, and designation of plants.	Number of seeds produced per head.							
	Heads not covered with tarlatan.				Heads covered with tarlatan.			
	A	B	C	D	E	F	G	H
Ames, 1911:								
No. 1	33	26	30	47	0	0	0	0
No. 2	40	46	39	26	0	0	0	0
No. 3	46	0	31	35	0	0	0	0
No. 4	40	69	20	36	0	0	0	1
No. 5	52	47	13	68	0	0	0	0
No. 6	54	18	52	56	2	0	0	1
No. 7	90	33	43	69	1	0	0	0
No. 8	44	57	62	40	0	1	0	0
No. 9	47	26	16	28	0	0	0	0
No. 10	82	55	59	65	0	0	3	0
Average	52.8	37.7	36.5	47.0	0.3	.1	.3	.2
Altoona, 1911:								
No. 11	26	13	24	5	0	1	0	0
No. 12	10	16	12	38	0	0	0	1
No. 13	29	12	4	7	0	0	1	0
No. 14	9	6	11	14	0	0	0	0
No. 15	22	16	28	0	0	0	0	0
Average	19.2	12.6	15.8	12.8	0	.2	.2	.2
Ames, 1912:								
No. 16	20	3	25	15	0	0	0	0
No. 17	33	31	24	36	0	0	0	0
No. 18	39	45	24	43	0	2	0	0
No. 19	20	40	28	21	0	0	0	0
No. 20	44	40	24	28	0	0	0	0
No. 21	52	61	51	52	0	0	1	0
No. 22	37	28	33	35	0	0	0	0
No. 23	40	35	40	21	0	0	0	0
No. 24	42	28	26	43	0	0	0	0
No. 25	15	5	6	12	0	0	0	1
Average	34.2	31.6	28.1	30.6	0	.2	.1	.1

Summary of Average Results for the Entire 145 Plants.

	A	B	C	D	E	F	G	H
Ames, 1911: 50 plants	44.3	38.8	35.1	42.3	0.08	0.16	0.16	0.22
Altoona, 1911: 25 plants	16.0	9.4	20.3	18.0	.28	.48	.24	.36
Ames, 1912: 70 plants	48.9	42.5	41.3	41.5	.1	.1	.14	.15
Average, 145 plants	41.6	35.5	35.5	37.7	.12	.18	.16	.21

The average seed yields given in the first part of Table II should be compared with the average seed production shown in the summary of the same table. The 25 plants listed separately were selected to represent all the plants upon which this experiment had been conducted in 1911 and 1912. While the average results shown by the selected plants vary somewhat from the results of all the plants, still they are representative of the plants as a whole. It will be noted that the seed production of the uncovered heads varies considerably on the same plant, so that final results must be taken from the average of treated heads on a number of plants rather than on a few plants. For this reason the results given in the summary more nearly represent true conditions than those given in the first part of Table II.

From the results obtained on the heads not covered with tarlatan it will be seen that artificial manipulation was detrimental to seed production, since the average yield of the check is higher than that

FIG. 4.—Heads of red clover covered with tarlatan to prevent pollination by insects.

of any treated series. This is undoubtedly due to the fact that the flowers were somewhat mutilated during the operation. Very little seed was obtained from the heads which were kept under cover and artificially manipulated. The few seeds obtained were probably the result of cross-pollination by bumblebees when the tarlatan cloth had been pushed against the heads by rain or had been cut by grasshoppers. Rains would wash the starch from the tarlatan, thus permitting it to fall against the clover heads and allowing the flowers to protrude. This was avoided by either straightening out the cloth after it had dried or re-covering the heads. A few flowers on some heads, however, were exposed to the action of insects for a very short time. In the work which was conducted at Altoona, Iowa the grasshoppers were so bad that some heads had to be re-covered as often as three times a day. Many uncovered heads were partly destroyed by the grasshoppers, and this undoubtedly accounts for the small seed yield of the uncovered heads, since bumblebees were plentiful.

HEADS COVERED AND NOT POLLINATED.

Another experiment was conducted in order to determine whether clover heads kept covered during their entire blooming period and not pollinated could set seed.

Plants having at least six heads which would come into bloom at approximately the same time were selected for this work. Fifty

FIG. 5.—General view of the field in which the clover work was conducted in 1912 at Ames, Iowa. The stakes represent plants selected for individual pollination work. The cages in the background were used to test the efficiency of different insects as pollinators of red clover.

plants at Ames and 25 at Altoona were selected in 1911 and 27 plants at Ames in 1912. The average seed yields per head are shown in Table III.

TABLE III.—*Average seed yields of clover heads which were covered with tarlatan and not pollinated.*

Location, year, and number of plants.	Heads covered with tarlatan.					
	A	B	C	D	E	F
Ames, 1911: 50 plants	0.1	0.11	0.15	0	0.16	0
Altoona, 1911: 25 plants	.16	.4	.35	.04	.26	.2
Ames, 1912: 27 plants	0	.1	0	0	.02	0
Average, 102 plants	.08	.17	.15	.009	.14	.04

To the results presented in Table III may be added the results given in column E of the summary of Table II, where 145 heads were covered, not treated, and used as checks in those experiments. From the 757 heads covered and not treated in 1911 and 1912 an average of 0.1 seed per head was obtained. The relatively high average obtained at Altoona in 1911 may undoubtedly be accounted for by grasshoppers mutilating the tarlatan which was used to cover the heads. On this account heads were occasionally exposed to the action of insects for a short time.

Since no more seed was produced by these heads than may be accounted for by insects working on the flowers when they were occasionally exposed for a short time on account of rains or grasshoppers, we may say that clover flowers must be pollinated by some agency before any seed is produced.

EFFECT OF SELF-POLLINATION.

Another experiment was conducted in which the clover heads were covered with tarlatan before any flowers opened and were kept covered, except while being worked, until mature. As soon as the flowers came into bloom they were self-pollinated by springing the keels of the flowers with toothpicks, care being taken to rub pollen upon each stigma. A separate toothpick was used for each head. In 1911, 125 heads were self-pollinated and 170 heads in 1912. An average of 0.16 seed per head was obtained in 1911 and an average of 0.09 seed per head in 1912.

The results of this experiment show, as have previous experiments, that red-clover flowers must be cross-pollinated in order to set seed on a commercial basis. The amount of seed obtained is so small that it was probably the result of bees working through the tarlatan, although the cytological work reported upon in this bulletin shows that it is possible to have an occasional seed produced from self-pollination.

SEED PRODUCTION OF HEADS UNDER ORDINARY FIELD CONDITIONS.

As a field check on the preceding experiments a number of heads were tagged in 1911 and 1912 and neither covered nor artificially pollinated. These heads were labeled in different parts of the field and Table IV shows the number of heads in each group and the average seed yield per head.

TABLE IV.—*Average seed yield of clover heads not covered or artificially pollinated.*

Location and year.	Number of heads collected.	Average number of seeds per head.
Ames, 1911	300	50.1
Do	532	55.4
Do	470	50.9
Altoona, 1911	150	43.6
Ames, 1912	65	53.4

The results given in Table IV are somewhat higher than the average seed yield of the uncovered check of the experiments summarized in Table II. It may be that the close proximity of the checks given in Table II to heads covered with tarlatan kept bees from making as many visits to those heads as they would otherwise have made.

FLOWERS POLLINATED WITH POLLEN FROM ANOTHER HEAD ON THE SAME PRIMARY BRANCH.

Since the amount of seed obtained in 1911 from self-pollinated heads under cover was so small that it could be accounted for by bees working through the tarlatan, it was not deemed necessary to emasculate the flowers for cross-pollination work in 1912. With this in view a series of heads was covered before any of the flowers came into bloom and later pollinated with pollen from another head on the same primary branch, 20 flowers on each of 11 heads being pollinated in this manner. Not a single seed was produced.

FLOWERS POLLINATED WITH POLLEN FROM A HEAD ON A DIFFERENT PRIMARY BRANCH OF THE SAME PLANT.

Another experiment similar to the preceding one was conducted, except that the pollen was taken from heads on different primary branches of the same plant, 20 flowers on each of 10 heads being pollinated in this manner. One seed was produced.

CROSS-POLLINATION EXPERIMENTS.

Alternately with the above two experiments 20 flowers on each of 13 heads were pollinated with pollen from a separate plant. An average of 14.3 seeds per head was obtained.

The results obtained in the last three experiments, as well as with all preceding ones, show that clover is practically self-sterile and that pollen must come from a separate plant in order to effect fertilization.

BUMBLEBEES AS CROSS-POLLINATORS OF RED CLOVER.

In view of the consensus of opinion that the bumblebee is responsible for the cross-pollination of red-clover flowers, and since no investigator, so far recalled, has denied its ability to do this, it was deemed desirable to study the relative efficiency of the bumblebee as a cross-pollinator of this plant.

For this work a cage 12 feet square and 6 feet high, made of wire screen having 14 meshes to the linear inch, was erected shortly after the first crop of clover had been cut. As soon as the second crop started to bloom bumblebees were caught with an insect net and placed in the cage. It was soon found that bees would live about three days when confined in the cage and that six bees in confinement would visit approximately as many flowers as one bee would have visited had it worked nearly all the time. With this in mind, two bumblebees were placed in the cage each forenoon until all the clover heads were mature. An area 4 feet square was marked off in this cage as soon as the clover was mature. From this area all heads were collected, kept separate, and thrashed by hand. Of the 311 heads collected from this area an average of 30.4 seeds per head was obtained.

Repeated field observations in Iowa in 1911 and 1912 showed that bumblebees were actively engaged in collecting nectar from eight to nine hours a day. Little work was done by them before the dew had entirely disappeared from the foliage and flowers or after 6 o'clock in the evening. Observations showed that bumblebees are able to pollinate 30 to 35 flowers a minute. However, they seldom visit more than eight to ten on a single head at one time.

These results agree closely with those of Pammel and King (32), who state that bumblebees pollinate on an average 30 flowers a minute, and Smith, according to Beal (3), who estimates from counts that old bees will visit 35 flowers a minute and young bees seldom more than eight.

HONEYBEES AS CROSS-POLLINATORS OF RED CLOVER.

The ability of the honeybee to cross-pollinate red clover has been discussed by scientific investigators and beekeepers for some time. Those who do not believe that the honeybee is able to pollinate red clover base their statements for the most part on the fact that the proboscis of the honeybee is not long enough to reach the nectar located at the base of the staminal tube. Some investigators and bee men state that some strains of the Italian race of honeybees are able to obtain some nectar from red-clover flowers, while other investigators say that honeybees collect pollen from red-clover flowers and thereby cross-pollinate them.

According to Knuth (22, v. 2, p. 289) the proboscis of the honeybee is 6 mm. in length, which is 3.6 mm. shorter than the average length of the corolla tubes of first-crop red-clover flowers. Honeybees may be able at times to obtain some nectar from the sides of the staminal tubes of red-clover flowers when a large amount is secreted or when the flowers are not in an upright position. Knuth (22, v. 2, p. 289) observes that *Bombus terrestris*, a species of bumblebee found in Europe, pierces the tubes of clover flowers and that honeybees later obtain nectar through these slits. *Bombus terrestris* has a proboscis from 7 to 9 mm. in length. While working on the experiments reported upon in this bulletin several corolla tubes were observed which had been slit at the base, but it can not be stated that these slits were made by bees. Schneck (34) states that the Virginia carpenter bee (*Xylocopa virginica*) slits the lower end of the corolla tubes of red-clover flowers and that he has observed honeybees obtaining nectar through the slits.

In order to determine the efficiency of the honeybee as a cross-pollinator of red clover, a cage 12 feet square and 6 feet high, made of galvanized-wire screen having 4 meshes to the linear inch, was erected in the same field as the bumblebee cage. It was previously determined that a mesh of this size would permit a honeybee, or any insect smaller than a honeybee, to pass through, but would not permit bumblebees to do so. Two weeks before the clover came into bloom a small colony of honeybees was placed in one corner of this cage (fig. 6). The bees soon learned to pass through the screen. By the time the clover began to bloom the bees had become accustomed to the cage, and while most of them worked on flowers outside, some could always be seen at work on the clover within the cage. Bees

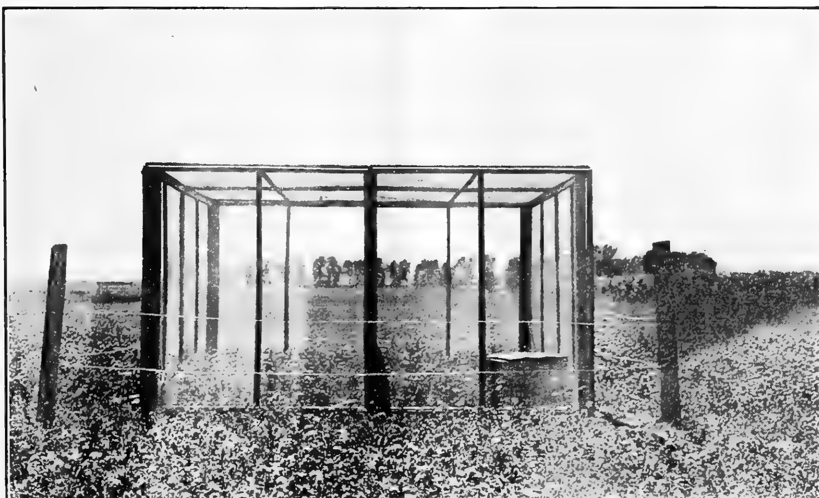

FIG. 6.—A screen cage in which a hive of honeybees was placed, in order to determine the efficiency of these insects as pollinators of red clover.

working on the clover within the cage were observed to collect pollen from the flowers and carry it to the hive.

As soon as all the flowers in the cage were mature, an area 4 feet square was measured off and all heads within this area were collected, kept separate, and thrashed by hand. Of the 623 heads collected from this area an average of 37.2 seeds per head was obtained.

The higher yield of seed obtained in the honeybee cage than in the bumblebee cage may be attributed, at least in part, to the larger number of bees which had access to this clover. However, the ratio of honeybees to bumblebees was no greater in the cages than in the clover fields in the vicinity of Ames in 1911.

In 1911 the precipitation at Ames was 2.48, 3.83, and 0.39 inches below normal for June, July, and August, respectively. When the clover was in bloom very few nectar-producing plants were to be found. Whether the honeybee would work on red clover to this extent in a year of normal rainfall when the number of other nectar-producing plants is larger is problematical, but our observations and results show that the honeybee is able to spring the keels of red-clover flowers and thereby cross-pollinate them.

MECHANICAL CROSS-POLLINATORS OF RED CLOVER.

A machine so constructed that a platform of brushes could be made to strike clover heads with a vertical stroke was placed on the market under the name of a clover cross-pollinizing machine (fig. 7). This machine received some favorable comment. In view of this fact, a number of experiments were outlined to test its efficiency and also

FIG. 7.—Clover cross-pollinizing machine.

to test the efficiency of different types of hand-operated brushes as mechanical cross-pollinators of red clover. Some plats of red clover were treated with various types of brushes at different times of day, while other plats were treated when the clover heads were in different stages of bloom. The direction of the strokes with the brushes was also varied in order to see whether this would have any effect on the yield of seed.

MACHINE POLLINATION EXPERIMENTS.

In order to determine the efficiency of a clover cross-pollenizing machine several experiments were performed at Ames in 1911. Machines similar to the one used were offered for sale on the market at the time these experiments were being conducted.

This machine was so constructed as to give vertical strokes with a brush 4 feet wide and 6 feet long. The brushes could be removed with little trouble and replaced with others of a different type. Two types of brushes were used in these experiments. Brush No. 1 was composed of palmetto fiber, the bristles of which were rather stiff and of a dark reddish-brown color. Brush No. 2 was composed of rice-root fiber of light color, somewhat more flexible than the palmetto fiber. The plats treated were 12 feet wide and 100 feet long.

The number of heads collected from each plat represents the number contained within two hooped areas. These hooped areas were obtained by sailing a hoop into the air so that it would light on a particular plat. Since each plat contained a uniform stand it was thought that by this method heads would be selected which would be representative of the entire plat. Table V shows the results obtained in these experiments.

TABLE V.—*Average seed yield of red clover on plats which were given various treatments with a cross-pollinizing machine.*

No.	Treatments.					Heads collected.	Seeds per head.
	Brush used.	Times gone over.	Time between.	Time of day.	Number of days given.		
			Days.				
Plat 1	No. 1	1	1	A. M.	7	460	63.3
Plat 2	No. 1	2	1	A. M.	7	424	59.4
Plat 3	No. 1	1	3	A. M.	4	499	64.2
Plat 4, check						490	65.1
Plat 5	No. 1	2	3	A. M.	4	414	59.2
Plat 6	No. 1	3	3	A. M.	4	458	70.3
Plat 7, check						582	66.7
Plat 8	No. 2	3	3	A. M.	4	527	70.9
Plat 9	No. 1	3	3	P. M.	4	487	64.7
Plat 10, check						655	64.0
Plat 11	No. 2	3	3	P. M.	4	492	67.4

It will be seen from the above experiments that the treatments with brush No. 1 decreased the yield 1.9 seeds per head, while the plats treated with brush No. 2 gave an increased yield of 3.9 seeds per head over the average of the check plats.

EFFICIENCY OF DIFFERENT HAND-OPERATED BRUSHES AS MECHANICAL CROSS-POLLINATORS OF RED CLOVER.

In order to test the efficiency of hand-operated brushes as a means of mechanical pollination of red clover, eight pairs having different types of bristles were used. The different pairs were labeled A, B, C, etc., for convenience in reference. Following is a brief description of the different pairs of brushes used:

(A) Rice-root fiber, somewhat stiff; bristles about 2 inches long and nearly erect.

(B) Rice-root fiber, similar to A, but with bristles 3 inches long, somewhat coarser and more spreading.

(C) Tampico fiber, finer but stiffer than the rice-root fiber in brushes A and B,

(D) Wire-bristle hairbrushes,

(E) Indian palmetto fiber, coarser than any of the others, but somewhat brittle. A portion of this brush was modified by cutting out sections of the bristles to make a more uneven surface.

(F) Ordinary bristle hairbrushes.

(G) Same as brush E, but with about half of the bristles clipped out.

(H) Same as brush C, but with about half of the bristles clipped out.

The idea of utilizing pairs of brushes with different types of fibers was to determine, if possible, if any of them would give sufficient promise to warrant an application of the particular type of brush to a mechanically operated machine that would imitate the action of the small brush when operated by hand. For this reason no brushes were used which could not be duplicated on a machine for operation on a field scale.

The work with the hand-operated brushes was done principally at La Fayette, Ind., and Ames, Iowa. In some experiments the heads were manipulated with the brushes at different times of day, while in other experiments different numbers of treatments were given the heads at varying intervals. The direction from which the heads were struck also varied in certain experiments, some being given vertical strokes and others lateral strokes. It was thought that cross-pollination might be brought about by the vertical stroke, which apparently would enable some of the brush bristles to spring the keels and convey pollen from one flower to another. It was also thought that if the flowers were self-fertile the lateral strokes would accomplish this. The representative tables that follow indicate the principal features brought out by this series of experiments.

RELATIVE EFFICIENCY OF BRUSHES WHEN THE CLOVER HEADS WERE STRUCK HORIZONTALLY.

In a clover field 2½ miles east of La Fayette, Ind., 26 square-rod plats were laid off for this experiment in 1911 (Table VI). All of the heads in bloom at the time the plats were marked off were removed.

Plat 1 was left as a check, no brushes being used on it. Plat 2 was worked with brushes A, one brush being taken in each hand and the blossoms struck between the brushes by a quick movement of the wrists. When in full bloom the heads received one treatment, the operator going only in one direction across the plat. Brushes B, C, D, E, and F were used on plats 3, 4, 5, 6, and 7, respectively, in the same manner as for brushes A on plat 2. Plat 8 was treated by going one way across it at right angles to the first way, thus giving each blossom two treatments, the strokes of the two treatments thus being at right angles to each other. Brushes A were used. Plats 9, 10, 11, 12, and 13 each received treatment similar to plat 8, but with brushes B, C, D, E, and F, respectively. Plats 14 and 15 were left as checks. Plats 16, 17, 18, 19, 20, and 21 each received two treatments with brushes B, C, E, B, C, and E, respectively, in the same manner as plat 8.

Two days later plats 16, 17, 18, 19, 20, and 21 each received two more treatments with brushes B, C, E, B, C, and E, respectively, and three days later plats 19, 20, and 21 each received an additional two treatments with brushes B, C, and E.

Plats 22 to 26, inclusive, were square-rod plats selected at intervals in the field immediately surrounding the portion laid off with the regular plats. These were designed to give a large number of check plats to show the variation in the field under ordinary conditions.

At harvest time 500 heads were picked at random from each of the 26 plats. These heads were hulled and the average seed production for the 500 heads is given in Table VI.

Table VI.—*Average seed yield per head obtained when clover heads were struck horizontally with different types of brushes and at different intervals at La Fayette, Ind., in 1911.*

No.	Strokes per treatment.	Brush used.	Date of treatment.	Heads collected.	Seeds per head.
Plat 1, check				500	58.2
Plat 2	1	A	August 2	500	46.0
Plat 3	1	B	do	500	67.1
Plat 4	1	C	do	500	50.1
Plat 5	1	D	do	500	27.0
Plat 6	1	E	do	500	39.4
Plat 7	1	F	do	500	34.7
Plat 8	2	A	do	500	44.0
Plat 9	2	B	do	500	35.4
Plat 10	2	C	do	500	59.4
Plat 11	2	D	do	500	27.2
Plat 12	2	E	do	500	34.7
Plat 13	2	F	do	500	59.9
Plat 14, check				500	49.3
Plat 15, check				500	57.0
Plat 16	2	B	August 2, 4	500	59.9
Plat 17	2	C	do	500	26.9
Plat 18	2	E	do	500	64.4
Plat 19	2	B	August 2, 4, 7	500	35.4
Plat 20	2	C	do	500	32.0
Plat 21	2	E	do	500	22.5
Plat 22, check				500	28.6
Plat 23, check				500	59.0
Plat 24, check				500	49.5
Plat 25, check				500	43.2
Plat 26, check				500	31.6
Average of all checks				4,000	47.0

Table VI shows that only 6 plats averaged higher than the average of the checks, whereas 12 plats averaged lower than the average of the checks. A variation almost as wide is shown in the 8 check plats as in the 18 treated plats, yet the results show that, as a whole, the brushes injured the seed production. The low results on the plats treated with brush D, the wire hair brush, were undoubtedly due to the fact that the wire bristles penetrated and injured the flowers.

This brush work was duplicated on a small scale with brushes A, B, and E on a few heads left uncovered and on heads that were covered with tarlatan, near La Fayette, in the summer of 1913. The heads were worked once. The results are given in Table VII.

TABLE VII.—*Average seed yield of clover heads which were struck horizontally with different types of brushes and either protected or unprotected from insects at La Fayette, Ind., in 1913.*

Brush used.	Strokes per treatment.	Heads left uncovered.		Heads covered with tarlatan.	
		Heads worked.	Seeds per head.	Heads worked.	Seeds per head.
A	1	3	37.4	1	0
B	1	5	38.8	1	0
E	1	5	50.1	2	0
Check	1	3	60.8	1	0
Do	1	5	57.5	1	0
Do	1	5	60.1	2	0

Table VII shows that in each case of the heads left uncovered the check produced the most seed. As in Table VI, the brushes apparently reduced the seed production. It will be noted also that both the brush-treated and untreated heads produced no seed when protected from insect visitation.

Experiments to test the relative efficiency of horizontal strokes with the different brushes were also conducted at Ames, in the summer of 1911. Ten plats 4 feet square were used. These plats were marked off by placing stakes at the corners and connecting these stakes with heavy cord. Plats 1 to 8 were each given one treatment on each of three consecutive days, with brushes B, A, E, C, F, D, G, and H, respectively, and plats 9 and 10 were left as checks. Duplicate tests, using the same brushes, respectively, on plats 37 to 44 were also made. The results are shown in Table VIII.

TABLE VIII.—*Average seed yield per head obtained when clover heads were struck horizontally with different types of brushes at Ames, Iowa, in 1911.*

Brush used.	Strokes per treatment.	Treatments.	Original tests.			Duplicate tests.		
			Plat No.	Heads worked.	Seeds per head.	Plat No.	Heads worked.	Seeds per head.
B	1	3	1	464	44.8	37	438	44.9
A	1	3	2	476	41.1	38	515	43.2
E	1	3	3	457	42.6	39	490	30.1
C	1	3	4	322	46.2	40	485	42.5
F	1	3	5	440	43.9	41	470	47.5
D	1	3	6	435	36.2	42	445	33.0
G	1	3	7	320	45.1	43	460	39.9
H	1	3	8	430	41.0	44	432	42.9
Check			9	532	55.4	9	532	55.4
Do			10	470	50.9	10	470	50.9

Table VIII shows that in every case where brushes were used the seed production fell below the yield of the check plats.

From the results obtained in Tables VI, VII, and VIII it is concluded that at least horizontal strokes with the brushes in question reduced the seed production on account of the flowers being mutilated by the brushes.

RELATIVE EFFICIENCY OF BRUSHES WHEN THE CLOVER HEADS WERE STRUCK VERTICALLY.

In order to test the efficiency of brushes in promoting cross-pollination by carrying pollen from one plant to another on the bristles of the brushes, experiments were conducted at Ames, Iowa, in the summer of 1911 on plats 13 to 20 with different pairs of brushes. A vertical stroke on each of three mornings, three days apart, was given. The plats were 4 feet square. At maturity all heads from each plat were collected, kept separate, and later thrashed.

The experiments on plats 21 to 28 were the same in all respects, except that one treatment when the flowers were in early bloom, instead of three treatments, was given each plat. Plats 9 and 10 were used as checks. The results are presented in Table IX.

TABLE IX.—*Average seed yield per head obtained when clover heads were struck vertically with different types of brushes at Ames, Iowa, in 1911.*

Brush used.	Strokes per treatment.	Plats given three treatments.			Plats given a single treatment.		
		Plat No.	Heads worked.	Seeds per head.	Plat No.	Heads worked.	Seeds per head.
Check		9	532	55.4	9	532	55.4
Do		10	470	50.9	10	470	50.9
B	1	13	366	37.0	21	442	46.8
A	1	14	490	42.0	22	440	33.8
E	1	15	440	42.1	23	420	45.0
C	1	16	521	45.3	24	415	38.9
F	1	17	416	39.3	25	380	54.5
D	1	18	476	37.7	26	400	45.9
G	1	19	510	41.8	27	430	48.1
H	1	20	462	44.7	28	436	49.0

Table IX shows that with the exception of plat 25 the treatment considerably reduced the yield below that of the lowest yielding check plat. The results of the treated plats 13 to 20, inclusive, taken as a whole show a decrease of four seeds per head less than the yield of plats 21 to 28, inclusive. This may be accounted for by the fact that plats 13 to 20, inclusive, received two more treatments with the brushes than plats 21 to 28, inclusive, and were therefore subject to more injury from the bristles of the brushes. It will be seen from these experiments that the vertical strokes with the brushes proved no more efficient than the horizontal strokes in the production of seed.

RELATIVE EFFICIENCY OF BRUSHES WHEN PRESSED TOGETHER BELOW THE CLOVER HEADS AND PULLED UPWARD.

Experiments were conducted in the summer of 1911, at Ames, Iowa, to determine the efficiency of pressing a pair of brushes together below the clover heads and pulling them upward with considerable force, but still not enough to break off the heads. The plats were 4 by 4 feet in size. Pair A of the brushes was used. Three treatments three days apart in the forenoon were given. The results are presented in Table X.

TABLE X.—*Average seed yield per head when brushes were pressed together below the clover heads and pulled upward, summer of 1911.*

No.	Heads worked.	Brush used.	Treatments.	Seeds per head.
Plat 9, check	532			55.4
Plat 10, check	470			50.9
Plat 11	432	A	3	39.2
Plat 12	460	A	3	40.9

Table X shows that this manner of treatment as well as the horizontal and vertical stroke treatments caused a decrease in the production of seed.

SUMMARY.

A study of the cytology of red-clover flowers shows that many of them contain infertile ovules. The percentage of infertile ovules is greater in the first crop than in the second crop. In the first crop many plants produce 100 per cent of infertile ovules, while in the second crop the percentage of infertility ranges from none to a high figure. The percentage of infertile ovules in red clover is probably correlated with moisture conditions.

The pollen grains of red clover are very sensitive to moisture. On account of this, there can be little effective pollination when the flowers are wet. Germination of the pollen grains takes place only within a limited range of variation in the water supply. It is probably true that the only function of the stigma is that of supplying the requisite amount of water to the pollen for germination.

The time between pollination and fertilization varies with the temperature of the atmosphere. The time between pollination and fertilization in July is approximately 18 hours, while in October it varies from 35 to 50 hours. An examination of 30 flowers which had been self-pollinated for 55 hours showed good germination on the stigmas but no fertilization. The pollen tubes made a slow growth and none exceeded 4 mm. in length. In flowers which had been self-pollinated for 90 hours one pollen tube attained a length of 7.5 mm., while the rest were 5 mm. or less in length. The pistils of red clover average about 12 mm. in length. Eggs were found to be disintegrating four days after the flowers opened.

The self-pollination and cross-pollination experiments which were conducted in the field checked up very closely with the results obtained from the cytological studies. The average yield of seed obtained on heads which were not pollinated and on heads which were self-pollinated in different ways was less than one-half of 1 per cent. This small yield of seed may be accounted for by the occasional access of bees to these heads for a very short time, on account of rains or grasshoppers mutilating the tarlatan which was used to cover the heads.

The bumblebee is an efficient cross-pollinator of red clover. Bumblebees are able to pollinate from 30 to 35 flowers a minute.

The honeybee proved to be as efficient a cross-pollinator of red clover as the bumblebee in 1911. When the precipitation was considerably below normal in June, July, and August, 1911, and but few nectar-producing plants were to be found, honeybees collected large quantities of pollen from red clover. In order to collect pollen they must spring the keels of the flowers. In doing this they cross-pollinate the flowers.

A clover cross-pollinizing machine which was offered for sale on the market did not prove to be an efficient cross-pollinator of red clover.

The various types of hand-operated brushes which were used did not prove efficient as cross-pollinators of red clover. In nearly all cases where these brushes were used the seed yield was decreased instead of increased. This was undoubtedly due to the bristles of the brushes injuring the flowers, since the average seed yield of the plats which received three treatments with the brushes was lower than that of the plats which received but one treatment.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 290

Contribution from the Office of Markets and Rural Organization, CHARLES J. BRAND, Chief

Washington, D. C. August 30, 1915.

RAIL SHIPMENTS AND DISTRIBUTION OF FRESH TOMATOES, 1914.[1]

By WELLS A. SHERMAN, *Specialist in Market Surveys*, and PAUL FROEHLICH and HOUSTON F. WALKER, *Scientific Assistants*.

INTRODUCTION.

There is probably no perishable vegetable commonly grown out of doors in the United States which appears upon the market through a longer season than does the tomato. Winter supplies are received from Cuba, and until railroad communication was interrupted by the recent troubles there was a constantly increasing production on the west coast of Mexico. The industry in Florida has been an important and rapidly increasing one until now shipments range around 5,000 to 6,000 carloads per year. The charts on page 6 show the average length of the shipping seasons for each of the principal producing areas and the relative quantities of tomatoes shipped from each of these districts. Florida opens the commercial shipping season in January, and throughout the first few months encounters comparatively little competition in the eastern markets. South Texas is a competitor during May and June, and it is possible that the production of this territory will be largely increased.

The two areas of important production which first come upon the market in direct competition are the southern Mississippi and east Texas areas. In each of these the heavy shipping season is short, extending through June and the first week of July. Every effort is made to rush the crop on the market as rapidly as possible. Practically all of the numerous growers in the State of Texas report that the shipping season begins about May 1 and ends about July 15. There are a few points, however, at which two crops of tomatoes are raised. From such points the second crop is shipped usually from

[1] About 95 per cent of the reports of shipments listed in this publication were furnished by railroad officials, to whom acknowledgment is made for their courtesy and assistance.

NOTE.—This bulletin is of general interest to tomato growers, shippers, dealers, transportation companies, and consumers, and to all engaged in the trade in tomatoes and vegetables.

3108°—Bull. 290—15——1

October 15 to January 1. In southern California the tomato shipping season can be extended the year round, as the tomato grows there as a perennial.

The Texas and Mississippi territories are followed by west Tennessee and New Jersey, the former overlapping the Texas and Mississippi areas, while New Jersey usually comes on the market when the shipping seasons close in these two States. Shipments from other States may be said in a general way to move over shorter distances and to be of importance in a smaller number of the large markets.

Cuban, Mexican, Florida, and south Texas tomatoes, as a rule, have been luxuries or semiluxuries. The first shipments from Mississippi and northeastern Texas generally bring high prices, but when the shipments from these areas reach their height, tomatoes may be said first to come within the reach of the general purchasing public.

METHODS OF CULTIVATION AND SHIPPING.[1]

The system of cultivation in practically all of the southern tomato districts is not calculated to result in the greatest possible production per acre, but is designed to hasten maturity and to give a crop of uniform smooth tomatoes which can be marketed within the shortest possible time. Plants are staked, trimmed, and topped, and the fruit even may be thinned to limit the quantity, hasten maturity, and perfect the appearance of the individual specimens.

Large quantities are wrapped individually and packed very carefully in what the consumer would call a perfectly green state. The producers, however, consider a tomato "mature" when it has reached full size and appears smooth and well filled out. They are called "ripe" when they show the first tinge of pink or reddish color.

Green wrapped stock is shipped long distances under ventilation without refrigeration; but nearly all ripe stock, whether wrapped or not, is shipped under refrigeration. The last of the southern crop frequently is wasted because it does not sell to advantage in competition with locally grown northern tomatoes. The latter are larger, as a rule, than those grown in the South, where varieties are selected for early production and smoothness rather than for the size of the fruit.

METHODS USED IN COMPILING DATA.

In this publication an effort has been made to list largely by railroad stations the actual shipments of tomatoes for table use in 1914. Practically all of this information has been obtained from, or checked by, transportation companies, and while this tabulation may not be complete, it is believed to approximate very closely the actual carload movement.

[1] Farmers' Bulletin 642, "Tomato Growing in the South," by H. C. Thompson, 1915.

In the summer of 1914 inquiries were addressed by the Office of Markets and Rural Organization to station agents at all points from which there was any reason to believe that tomatoes were shipped in full carloads, and to every cooperative association handling the crop of which the department had any knowledge, asking for a record of the car-lot shipments in 1913 and an estimate of the shipments to be made in 1914. A growers' list was compiled with the object of obtaining reliable information on every phase of tomato marketing. After the shipping season of 1914 was ended the inquiry was renewed and has been followed up both by addressing local station agents and general railroad officials, until this office has definite reports on the shipments during 1914 from 330 shipping points at which tomatoes originate in car lots, and a statement from the transportation or shipping agencies as to the number of carloads shipped from each in that year.

DETAILED REPORT OF SHIPMENTS.

The tabulated statement placed at the conclusion of this bulletin shows the tomato shipping stations and the reported number of cars shipped from each during the 1914 season. No attempt has been made to list stations where no full cars originated. Yet at those stations where full cars did originate, the less than car-lot shipments have been ascertained, and have been reduced to equivalent carloads, and these are included in the tables here shown. The number of carloads shipped from many points varies greatly from year to year, due to seasonal variation and to the fact that the tomato crop, if unprofitable in any one section in any one year, is likely to be much reduced the next. For this reason the figures given for 1914 may be either much above or much below the average shipments, and there are no authentic figures for preceding years for comparison. In some cases certain stations are credited with less than car-lot shipments. The fact is that these stations normally ship in full carloads, but, owing to a short crop or other abnormal conditions in 1914, they did not ship their usual quantities. These figures are classified by States, and to some extent by shipping districts.

SHIPMENTS BY BOAT.

There are a number of localities in which the situation as to tomato shipments is somewhat complicated. This is particularly true of the territory surrounding the lakes and bays where many of the shipments are made by boats to markets located comparatively near to the points of origin. There are many small boat lines that handle considerable quantities of this commodity, and it has been found almost impossible to secure complete and accurate records of all these shipments. For instance, the region in the neighborhood of Benton

Harbor and St. Joseph, Mich., ships large quantities of tomatoes by boat to Chicago, and the region along Chesapeake Bay ships in the same manner considerable amounts to near-by cities.

LOCAL SHIPMENTS.

Near many cities large quantities of tomatoes are carried to market by trucks, electric lines, and other local transportation facilities. This renders it impossible to secure complete records of the entire commercial crop. Our main effort has been to secure material which will show the location and relative importance of the several districts which supply the major part of the tomatoes shipped to market over comparatively long distances. The data for Florida shipments in 1914 are unavoidably incomplete, inasmuch as one railroad system handling large quantities of Florida tomatoes has not yet submitted any report.

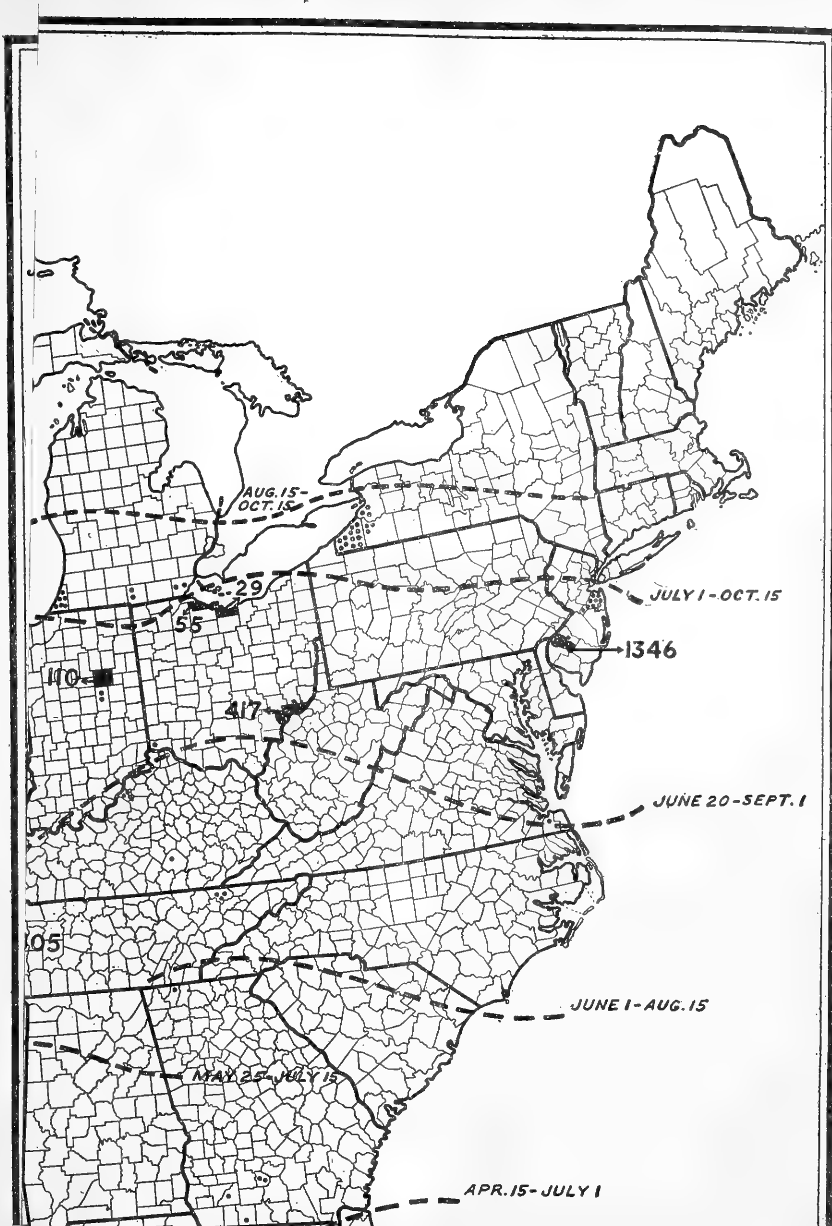
EXPLANATION OF MAP.

The accompanying map indicates the actual shipments of fresh tomatoes to market in the season of 1914. Each dot represents five cars, or fraction thereof. These dots are grouped in the county in which the stations are located, although it is well known that production does not actually follow the county lines. In cases where shipments are too heavy to be represented by dots the counties have been blacked in and the actual number of cars shipped given in figures. The size of the blackened area is not directly in proportion to the quantity shipped, but exact comparisons may be made by consulting the tabulation. The use of the county as the unit in map graphics necessitates this system.

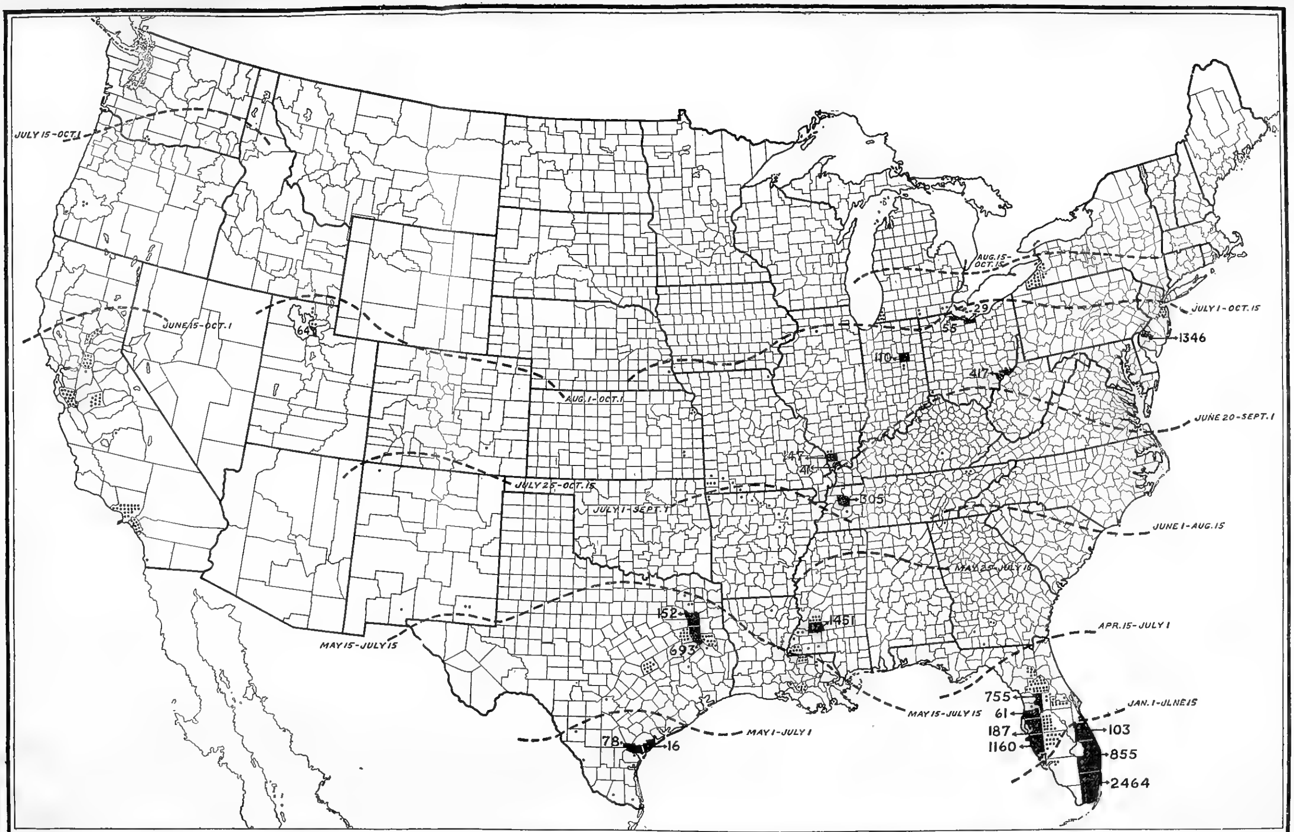
The dates within which the various areas ship are shown by curved lines, all of the areas shipping at a given period being grouped in a zone under the line representing that period. The map in this way shows at a glance the various competing areas as well as the dates of heaviest crop movement. These dates are, of course, subject to seasonal variation of considerable extent.

TOMATOES FOR CANNING.

An important element in the tomato situation is the cannery supply. It is undoubtedly true that more tomatoes go to the canneries than to market as table stock. The modern methods of preparing this canned product have rendered it so wholesome and palatable, as well as economical, that this industry has developed very rapidly. Certain localities—Delaware and the eastern shore of Maryland and Virginia, and large areas in New York State, for instance—produce considerable quantities of tomatoes for this purpose. It is a fact, however, that general conditions as to quantity,



are no other States reported as having shipments reaching 100 cars.



U. S. Dept. of Agriculture, Bulletin 290.
3108°—15 (To face page 4)

FIG. 1.—Map showing tomato shipments during the year 1914. Each dot represents 5 carloads (or fraction thereof). Black areas represent number of carloads indicated by figures.

quality, and price of table stock, when the supplies are locally obtained, are much modified by the presence of canneries. When prices warrant it on account of small crop or poor transportation facilities from other regions a considerable amount of the crop ordinarily going to canneries may be placed upon the market fresh, while on the other hand a plentiful supply will cause very much larger quantities to be offered to the canneries. There are certain localities where the climatic conditions are such that cannery stock can be raised profitably, but where under ordinary conditions it is not profitable to produce tomatoes to ship fresh for table use. This is sometimes due to the long distance to market and the small local consuming population. A careful investigation of the cannery situation in reference to this crop undoubtedly will aid very much in a clear understanding of the whole tomato marketing situation.

The effort has been made to separate all figures for tomatoes used for canning stock and include in these tabulations only those shipped for table use. It is very difficult to distinguish accurately between shipments to market and shipments to canneries from the records of carriers in many sections. The tabulation on page 7 shows a total of 11,995 carloads of tomatoes shipped for table use last year and it has been estimated that a somewhat greater number is grown for canneries, catsup factories, etc. The figures of the National Canners' Association show that 15,222,000 cases of tomatoes (No. 3 size, 24 cans to the case) were packed during the 1914 season. It is possible that a few hundred cars included in the following tabulation were so used. On this account there may be slight errors in the figures for some sections.

The line of demarcation between the regions where the production is principally for table stock and those regions where the crop is grown both for local consumption and for canning probably would pass east and west across the United States through the lower Ohio Valley, and through southern Virginia to Norfolk, the region to the south of this imaginary line specializing in table stock in car lots.

COMMERCIAL SUPPLY OF TABLE TOMATOES.

The total reported shipments of table stock for 1914 were 11,995 cars, nearly one-half of the entire crop being shipped from the State of Florida, which is practically without competition so far as the production of tomatoes for table use is concerned, as the season there is so early that there are few other districts shipping when the Florida product is put on the market. The States next in importance are Mississippi, New Jersey, and Texas, each shipping from 1,100 to 1,500 cars. Ohio and California ship approximately 400 cars each; Tennessee, 300; Illinois, 200; and Indiana, 125. There are no other States reported as having shipments reaching 100 cars.

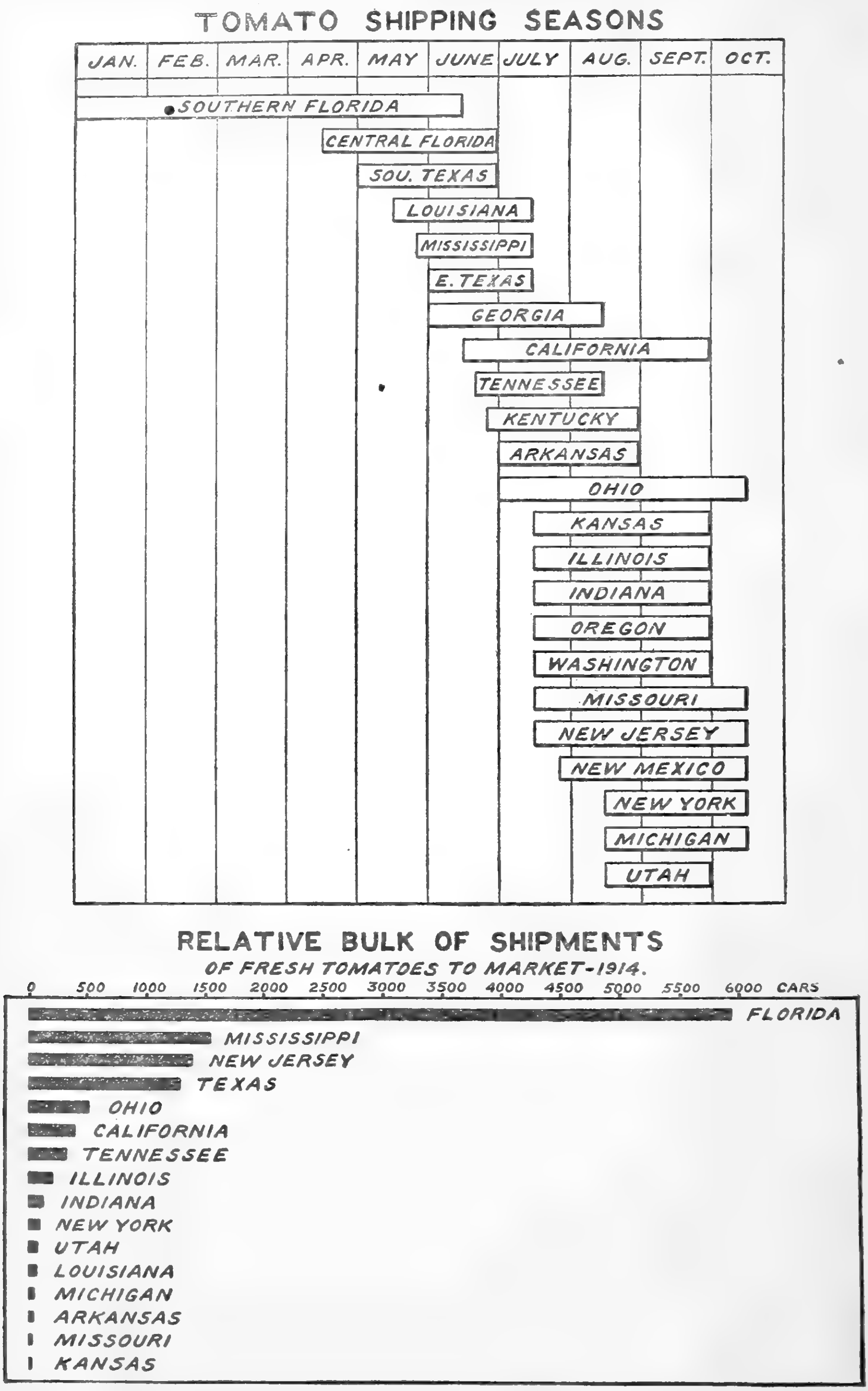


FIG. 2.—Chart showing shipping seasons and amount of fresh tomatoes shipped to market, by States, 1914.

DIFFICULTIES ENCOUNTERED.

Some of the railroads do not keep separate records for tomatoes shipped, but classify them together with a number of other commodities as "vegetables." This has increased to a very considerable degree the difficulty of securing the information here presented. Many of the transportation companies have indicated a willingness to separate this product in their records. Owing to the importance of the crop, it is hoped that all of the transportation companies will adopt such a system. One of the important factors in marketing any crop is, of course, a knowledge of the amount marketed the preceding year, and the probable amount to be handled during the current season.

It is realized that a survey of this character presents many difficulties and can be perfected only as it is subjected to the criticism and correction of the trade, railway officials, and shippers. This compilation and the map showing graphically the location of the important tomato shipping areas and the approximate dates for shipments is believed to be the most comprehensive statement of the commercial tomato crop that has been attempted, and it is published with the belief that it will be found immediately useful to all concerned in marketing the tomato crop in 1915. It is hoped to perfect this work and to make it much more complete in the future.

TOMATO SHIPMENTS, 1914.

All numbers which are marked with an asterisk (*) are estimates, based upon the shipments for 1913 and figures furnished for the 1914 crop previous to its being marketed. Stations believed to be important shipping points but for which no figures have been obtained are marked with a dash (——).

	Carloads.
ALABAMA:	
(May 25 to July 1.)	
Evergreen	0.0
State total	0.0
ARKANSAS:	
(July 1 to Sept. 1.)	
White River district	30.0
Decatur	9.0
Judsonia	2.0
Gravette	1.0
State total	42.0
CALIFORNIA: [1]	
(June 15 to Oct. 1.)	
Henderson	*60.0
Sacramento	60.0
Merced	47.0
Los Angeles	45.0
Marysville	41.0
Fullerton	39.0
Monte	23.0
Sunnyvale	22.0
Anaheim	11.0
San Fernando	10.0
Florin	5.0
Lodi	5.0
Atwater	3.0
Freeport	3.0
Puente	3.0
San Diego	3.0
San Pedro	3.0
Mayfield	2.0
Mountain View	2.0
Placentia	2.0
San Francisco	2.0
Alviso	1.0

[1] The following shipments of tomatoes in 1914 were reported too late to appear on the map and chart: From Decoto, Cal., 95 cars.

California—Continued. (June 15 to Oct. 1)—Contd.	Carloads.
Dinuba	1.0
Earl	1.0
Gardena	1.0
Lawrence	1.0
Newmark	1.0
Pasadena	1.0
San Jose	1.0
San Juan Capistrano	1.0
Torrance	1.0
Whittier	1.0
Wilmington	1.0
Lincoln	0.0
State total	403.0
Colorado:[1] (Aug. 1 to Sept. 15.)	
Rocky Ford	1.0
State total	1.0
Florida:[1] (Southern section, Jan. 1 to June 15.)	
Dania	354.0
Peters	303.0
Pompano	223.0
Homestead	199.0
Colohatchee	198.0
Goulds	193.0
Hallandale	183.0
Fort Lauderdale	181.0
Deerfield	174.0
Delray	167.0
Boynton	151.0
Larkins	150.0
Naranja	144.0
Kendal	95.0
Arch Creek	87.0
Ojus	73.0
Fulford	63.0
Black Point	60.0
Jupiter	59.0
Miami	56.0
Bocaratone	55.0
Fellsmere	48.0
Perrine	41.0
Littleriver	37.0
Quay	19.0
Cocoanut Grove	18.0
Fort Myers	15.0
Yamato	15.0

Florida—Continued. (Southern section, Jan. 1 to June 15)—Continued.	Carloads.
Rockdale	14.0
Stuart	9.5
Viking	9.0
Wabasso	9.0
Lake View	8.0
Benson	6.0
Detroit	5.0
Fort Pierce	5.0
Vero	5.0
Biscayne	2.5
Hobe Sound	1.0
Modello	1.0
Buena Vista	0.0
Iona	0.0
Jensen	0.0
Sanibel	——
Total	3,436.0
(Central section, Apr. 15 to July 1.)	
Palmetto	776.0
Coleman	450.5
Bushnell	152.0
Ellenton	116.0
Parish	92.0
Plant City	90.0
Webster	89.5
Manatee	74.0
Wimauma	74.0
Dade City	61.0
Sarasota	46.0
Bartow	42.0
Fort Green Springs	35.0
Anthony	31.0
Gainesville	30.0
Wildwood	23.0
Oxford	20.3
Terra Ceia	19.0
Winter Garden	15.0
Tildenville	14.0
Homeland	13.0
Lakeland	13.0
Bradentown	12.0
St. Catherine	11.0
Tampa	11.0
Bowling Green	10.5
Dallas	10.0
Lowell	* 10.0
Ocala	10.0

[1] The following shipments of tomatoes in 1914 were reported too late to appear on the map and chart: From State of Colorado, 130 cars; from Sanibel, Fla., 75 cars.

FLORIDA—Continued.

(Central section, Apr. 15 to July 1)—Continued.

	Carloads.
Erie	9.0
Irvine	9.0
Knights	9.0
Nocatee	9.0
Sparr	9.0
Sumterville	9.0
Belleview	8.0
Oak	8.0
Oneco	8.0
Summerfield	8.0
Vegetable Siding	8.0
Tavares	7.0
Santos	5.0
Orlando	4.3
Bradley Junction	4.0
Eagle Lake	4.0
Leesburg	4.0
Zellwood	4.0
Brooksville	*3.0
Fort Green	3.0
McDonald's Siding	3.0
Murdock	3.0
Turkey Creek	3.0
Montverde	2.0
Ray	2.0
South Lake Weir	2.0
Geneva	1.5
Melbourne	1.5
Hawthorn	1.0
Montclair	1.0
West Apopka	1.0
Kathleen	0.5
Hampton	0.3
Fairvilla	0.0
Malabar	0.0
Ocoee	0.0
Orange Lake	0.0
Sydney	0.0
Theressa	0.0
Arcadia	—
Center Hill	—
Evinston	—
McIntosh	—
Micanopy	—
Reddick	—
Total	2,504.9
State total	5,940.9

GEORGIA:

(June 1 to Aug. 15.)

	Carloads.
Tifton	6.0
Thomasville	4.0
Cohutta	2.0
Camilla	1.5
Soperton	0.0
Vidalia	0.0
State total	13.5

ILLINOIS:

(July 15 to Oct. 1.)

Anna	70.0
Cobden	51.0
Grand Chain	41.0
Alto Pass	25.5
Makanda	10.0
Moccasin	5.0
Amboy	4.0
Alma	0.5
State total	207.0

INDIANA:[1]

(July 15 to Oct. 1.)

Fairmount	110.0
Alexandria	8.0
Princeton	—
State total	118.0

KANSAS:

(July 15 to Oct. 1.)

Leavenworth	13.0
Humboldt	7.0
State total	20.0

KENTUCKY:

(June 25 to Sept. 1.)

La Grange	13.0
Science Hill	2.0
Middletown	0.0
State total	15.0

LOUISIANA:

(May 15 to July 15.)

Napoleonville	28.0
Norwood	26.0
New Orleans	6.0
Roseland	6.0
Monroe	2.5
Jackson	0.5
Bunkie	0.0

[1] The following shipments of tomatoes in 1914 were reported too late to appear on the map and chart: From New Albany, Ind., 6 cars.

	Carloads.
LOUISIANA—Continued.	
(May 15 to July 15)—Contd.	
Shreveport	0.0
Zachary	——
State total	69.0
MICHIGAN:	
(Aug. 15 to Oct. 15.)	
Benton Harbor	28.0
Jonesville	7.0
Monroe	5.0
Petersburg	4.0
Grand Rapids	——
State total	44.0
MISSISSIPPI:	
(May 25 to July 15.)	
Hazlehurst	650.0
Crystal Springs	609.0
Gallman	100.3
Hopewell	52.1
Terry	35.0
Centerville	29.0
Wesson	13.0
Gatesville	10.3
Fayette	8.0
Martinsville	7.0
Georgetown	5.6
McComb	5.0
Natchez	3.5
Rockport	2.6
Gloster	2.5
Liberty	1.5
Beauregard	1.0
West	0.4
Weathersby	0.3
Enterprise	0.1
Osyka	0.1
Braxton	0.0
Monroe	0.0
Shivers	0.0
Tylertown	0.0
State total	1,536.3
MISSOURI:	
(July 15 to Oct. 15.)	
White River district	17.0
Neosho	13.0
Alexandria	1.0
State total	31.0

	Carloads.
NEBRASKA:	
(July 15 to Oct. 1.)	
Nebraska City	3.0
State total	3.0
NEW JERSEY:	
(July 15 to Oct. 15.)	
Swedesboro	1,346.0
Morganville	50.0
Sicklertown	1.0
Tuckahoe	0.0
State total	1,397.0
NEW MEXICO:	
(July 25 to Oct. 15.)	
Lakewood	9.0
Farmington	1.5
Mesilla Park	1.0
Las Cruces	0.5
State total	12.0
NEW YORK:	
(Aug. 15 to Oct. 15.)	
Forestville	18.5
Dunkirk	16.0
Perrysburg	15.0
Angola	14.0
Sheridan	7.0
Westfield	6.0
Smiths Mills	5.0
Portland	3.0
Vineyard	3.0
Brocton	2.0
Irving	0.2
Silver Creek	0.0
State total	89.7
OHIO:	
(July 1 to Oct. 15.)	
Marietta	331.0
Lowell	80.5
Genoa	49.0
Berlin Heights	23.0
Avery	6.0
Waterford	5.1
Elmore	4.0
Port Clinton	2.0
Harrison	1.0
New Philadelphia	0.5
Geneva	0.1
Ashtabula	0.0
State total	502.2

	Carloads.
OREGON:	
(July 15 to Oct. 1.)	
Dillard	11.0
State total	11.0
SOUTH CAROLINA:	
(June 1 to Aug. 1.)	
Charleston	0.0
Beaufort	—
Burton	—
State total	0.0
TENNESSEE:	
(June 20 to Aug. 15.)	
Humboldt	126.0
Gibson	70.0
Milan	57.5
Bradford	24.0
Medina	14.0
Tazewell Station	11.0
Cades	8.0
Fruitland	3.0
Jackson	3.0
Trenton	2.0
Oakfield	1.5
Dyer	0.5
Arlington	0.0
Sitka	0.0
West	0.0
Chattanooga	—
State total	320.5
TEXAS:	
(Southern section, May 1 to July 1.)	
Aransas Pass	40.0
Ingleside	37.0
Rockport	16.0
San Benito	4.0
Asherton	3.0
Corpus Christi	3.0
Carrizo Springs	2.0
Mission	2.0
Islitas	1.5
Portland	0.5
Poteet	0.3
Donna	0.0
Harlingen	0.0
Olmito	0.0
Total	109.3
TEXAS—Continued.	
(Eastern section, June 1 to July 15.)	
Jacksonville	225.0
Craft	65.0
Dialville	63.0
Turney	63.0
Alto	62.0
Gallatin	57.0
Frankston	50.0
Mount Selman	46.0
Tyler	43.0
Milano	42.0
Bullard	33.0
Maydelle	27.0
Arp	24.0
Frys Gap	24.0
Redlawn	24.0
Ironton	19.0
Pepperwine	17.0
Rusk	15.0
Flint	14.0
Gresham	14.0
Whitehouse	14.0
Ogburn	9.0
Caro	8.0
Cushing	8.0
Nacogdoches	7.0
Sacul	7.0
Goodson	6.0
Appleby	5.5
Clawson	4.0
Dodge	4.0
Lindale	4.0
Sulphur Springs	4.0
Delmer	2.0
Elkhart	2.0
Reese	1.0
Van Raub	1.0
Edgewood	0.5
Liberty	0.1
Boerne	0.0
Hitchcock	0.0
Livingston	0.0
Longview	0.0
Palestine	0.0
Reynolds	0.0
Tenaha	0.0
Willis	0.0
Winnsboro	0.0
Alvin	—
Ponta	—
Total	1,014.1
State total	1,123.4

	Carloads.
Utah:	
(Aug. 15 to Oct. 1.)	
Clearfield	60.0
Roy	6.0
Willard	5.0
Kaysville	4.0
Brigham	2.0
State total	77.0
Virginia:	
(July 1 to Sept. 1.)	
Norfolk	3.5
Accotink Station	——
State total	3.5
Washington:	
(July 15 to Oct. 1.)	
White Salmon	*15.0
State total	15.0
Grand total	11,995.0

PUBLICATIONS OF THE DEPARTMENT.

Department Bulletin 237. Strawberry supply and distribution in 1914. By Wells A. Sherman, Houston F. Walker, and O. W. Schleussner. 1915.

Department Bulletin 266. Outlets and methods of sale for shippers of fruits and vegetables. By J. W. Fisher, jr., J. H. Collins, and Wells A. Sherman. 1915.

Department Bulletin 267. Methods of wholesale distribution of fruits and vegetables. By J. H. Collins, J. W. Fisher, jr., and Wells A. Sherman. 1915.

Farmers' Bulletin 642. Tomato growing in the South. By H. C. Thompson. 1915.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 291

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER. January 25, 1916

BREEDING MILLET AND SORGO FOR DROUGHT ADAPTATION.

By A. C. Dillman, *Physiologist, Office of Alkali and Drought Resistant Plant Investigations.*

CONTENTS.

INTRODUCTION.

In the course of investigations which have as their object the perfection of methods for testing the comparative drought resistance of crop plants and for breeding drought-resistant varieties, two strains of millet and one of sorgo have been developed. These strains give evidence of being more uniform, more productive, and better adapted to the climatic conditions of the north-central Great Plains than the varieties generally grown in that region. The object of the present publication is to point out those characteristics of the new strains which indicate their value to dry-land agriculture in the Great Plains region.[1]

THE PLACE OF MILLET AND SORGO IN THE AGRICULTURE OF THE GREAT PLAINS.

It is becoming more and more evident that successful farming in the Great Plains must include the raising of live stock. The estab-

[1] By cooperative arrangement with the Office of Forage-Crop Investigations these strains will be tested at numerous dry-land stations in comparison with other varieties of the same crops, in order that their relative merit and range of geographical adaptation may be fully ascertained. It seems desirable, however, to publish an account of them at this time, since they give every indication of being superior to the ordinary commercial varieties of sorgo and millet which are now grown in the northern portion of the Great Plains area.

The earlier results of these investigations have been reported in a previous publication, which also gives fuller details of the plant-breeding methods. See Dillman, A. C., Breeding drought-resistant forage plants for the Great Plains area, U. S. Dept Agr., Bur. Plant Indus. Bul. 196, 1910.

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lished settlers in this region are those who have depended on live stock as their main source of income. In favorable seasons grain crops are profitable, but the profit from growing them can doubtless be increased if a portion of the grain is consumed on the farm as feed for animals. In the driest seasons, however, when small grains are likely to be a total failure, forage crops sufficient to carry animals through the winter can nearly always be depended on. This is because the most drought-resistant forage crops can be raised on a much smaller supply of moisture than the grain crops.

The native range is used to a large extent for summer pasturage, but it is necessary to produce under cultivation most of the forage for winter feeding, and it is often necessary to supplement the summer pasturage with cultivated crops. It is evident, therefore, that forage crops should occupy a very important place in the agriculture of the Great Plains.

In some sections of the northern Great Plains alfalfa, brome-grass, and other perennial crops give excellent results, but certain annual forage crops appear to be much more dependable in the central Plains. Two of the most suitable crops for this region are the millets and sorghums. Millets grow and mature in a comparatively short season and are often able to escape drought when other crops are overtaken. Sorghums endure drought well, standing a long period of drought and yet renewing growth upon the return of favorable conditions. Both crops have a very low water requirement.

ADAPTATIONS TO DROUGHT IN MILLET AND SORGO.

ROOT DEVELOPMENT.

Millet has a comparatively shallow root system with a great development of fine fibrous roots. It is therefore well adapted to make the best use of light rains which wet the soil to a depth of only a few inches. The early root growth is somewhat slow, so that the young plants are sometimes injured by high winds before the roots are well enough established to hold the plants firmly. Sorgo has a much deeper root system than millet and can apparently make use of moisture which is stored 3 or 4 feet deep in the soil. Both crops draw heavily upon the supply of soil moisture and are likely to use for their growth all of the water that is available in the area penetrated by their roots.

EARLY MATURITY.

The period of growth of the crop is of great importance under dry-land conditions. The ideal crop is one that will mature in a short season and therefore lessen the risk of being overtaken by drought. The short-season crop has the further advantage of allowing the soil to lie fallow for a considerable period of the year when moisture conservation may be practiced and the largest possible quantity of water stored in the soil for the use of the following crop. The strain of millet (Dakota Kursk) described in this bulletin may be cut for hay in from 70 to 75 days after planting and will mature seed in 90 days. The early strain of sorgo (Dakota Amber) described here matures seed in a period of 95 to 100 days from the date of planting and is sufficiently mature for forage in 15 days less time.

DROUGHT ENDURANCE.

The most important adaptation to drought presented by sorgo is its ability to revive quickly after a period of drought. The crop may cease growth for a considerable time during a dry period, but if a heavy rain occurs it will then revive and make a rapid growth. This was the case at Akron, Colo., in 1910, when a dry period during June and July allowed only a limited growth of the crop and caused the plants to produce seed heads earlier than usual. A rain of 2.8 inches on August 4, however, caused a vigorous secondary growth, so that the plants produced additional seed heads, which were fully two weeks later in maturing than the seed first formed.

Millet shows much less drought endurance than sorgo, but it compares favorably with the small grains and corn.

LOW WATER REQUIREMENT.

A low water requirement[1] is an important factor in the adaptation of plants to conditions of drought. In this respect millet and sorgo are preeminent among drought-resistant crops. At the Belle Fourche (S. Dak.) station in 1912 millet had a water requirement of 240, as compared with 460 for wheat and 735 for alfalfa; that is, the quantity of water which was required to produce 1 ton of dry matter (hay and grain) in a mature millet crop would produce only 1,043 pounds of dry matter (hay and grain) in the form of a mature wheat crop and only 654 pounds of dry matter in the form of alfalfa hay. In experiments conducted at Akron, Colo., Briggs and Shantz found that the water requirement of sorgo is only slightly higher than that of millet. The water requirement of millet and sorgo is further discussed elsewhere in this bulletin.

CLIMATIC CONDITIONS.

Crop production in the Great Plains is largely dependent upon the amount of rainfall which occurs during the growing season of the crop. By means of summer fallowing a part of the precipitation of one season may be stored in the soil for the benefit of the following

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[1] "The term 'water requirement' is used . . . to indicate the ratio of the weight of water absorbed by a plant during its growth to the weight of dry matter produced." (Briggs, L. J., and Shantz, H. L. The water requirement of plants. 1.—Investigations in the Great Plains in 1910 and 1911. U. S. Dept. Agr., Bur. Plant Indus. Bul. 284, p. 7, 1913.

crop, but the amount of moisture stored in this manner usually is not enough in itself to mature a crop, though it is oftentimes first-class insurance against complete failure.

The plant-breeding work here reported has been conducted on the United States experiment farms at Newell, S. Dak., and Akron, Colo. At Akron the average annual precipitation from 1908 to 1914, the seven-year period covered by these investigations, was 17.66 inches; at Newell the average was 13.03 inches for the same period. The average seasonal rainfall (April to August, inclusive) was 11.33 inches at Akron and 8.20 at Newell.

The annual and seasonal rainfall for each year is shown in Table I.

Table I.—*Annual and seasonal rainfall at Newell, S. Dak., and Akron, Colo., from 1908 to 1914, inclusive.*

Period and location.	1908	1909	1910	1911	1912	1913	1914	Average.
Annual:	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Newell, S. Dak.	14.16	17.73	12.55	6.74	16.09	12.53	11.39	13.03
Akron, Colo.	16.63	22.46	17.36	14.51	20.73	16.35	15.58	17.66
Seasonal:								
Newell, S. Dak.	8.46	13.30	7.19	3.78	10.87	5.94	7.86	8.20
Akron, Colo.	11.26	13.97	12.59	7.90	13.90	7.97	11.72	11.33

It will be seen that the moisture conditions at Akron have been much more favorable than at Newell during the period specified, even when we take into consideration the greater evaporation at Akron, which reduces somewhat the effectiveness of the greater amount of rainfall.[1]

BREEDING MILLET FOR ADAPTATION TO DROUGHT.

Preliminary tests[2] showed that the smaller and earlier varieties of millet (Kursk, Siberian, and Common) were more valuable under conditions of drought than the larger and later maturing varieties (German and Hungarian). The latter were therefore discarded and a large number of individual plants which showed evidence of adaptation to drought were selected among the earlier ripening varieties. In making these selections the aim was also to secure plants having a good forage type, stooling freely, fine in texture, and leafy, combined with desirable seed habits. Simple selection, without hybridization, was the method used throughout. The original stocks of the varieties with which the work was begun showed abundant variation, and the improvement accomplished has been the result of segregating the superior strains.

[1] For a full discussion of this subject, see Briggs, L. J., and Belz, J. O., Dry farming in relation to rainfall and evaporation., U. S. Dept. Agr., Bur. Plant Indus. Bul. 188, 71 p., 23 fig., 1 pl., 1910.

[2] Dillman, A. C. Breeding drought-resistant forage plants for the Great Plains area. U. S. Dept. Agr., Bur. Plant Indus. Bul. 196, p. 25. 1910.

FIG. 1.—DAKOTA KURSK MILLET, SHOWING THE ERECT, LEAFY GROWTH OF THE PLANTS AND THE ERECT OR INCLINED HEADS.

Photographed at Newell, S. Dak., August 23, 1912.

FIG. 2.—SIBERIAN MILLET (A. D. I. NO. 4—3), OF COARSER TYPE THAN THE DAKOTA KURSK AND HAVING LARGE DECLINED OR DROOPING SEED HEADS.

Photographed at Newell, S. Dak., August 23, 1912.

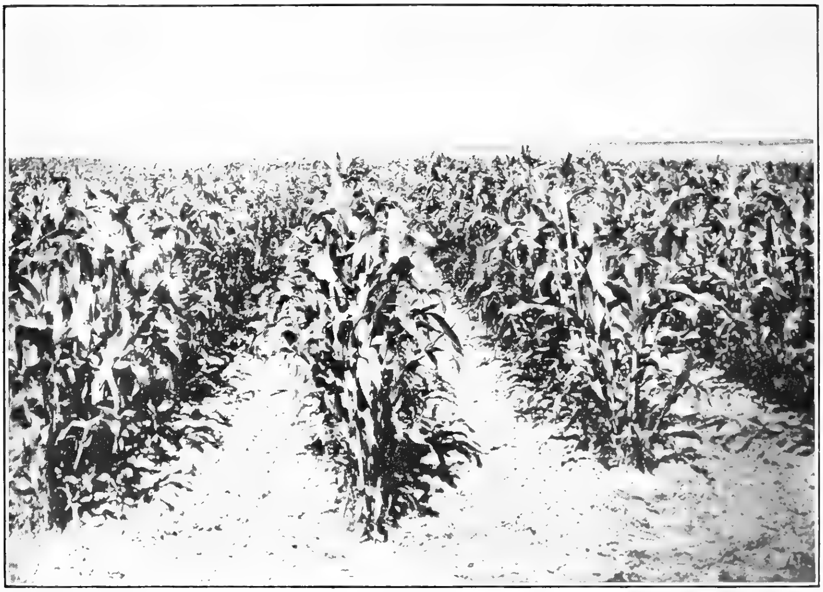

FIG. 1.—DAKOTA AMBER SORGO, SHOWING ITS COMPARATIVELY LEAFY HABIT OF GROWTH.

Photographed at Akron, Colo., July 22, 1912.

FIG. 2.—DAKOTA AMBER SORGO, SHOWING A CLOSER VIEW OF SOME NEARLY MATURE PLANTS.

Photographed at Newell, S. Dak., August 22, 1914.

Several of the selected individuals gave rise to uniform and productive strains. Comparative-yield tests of these strains, both in drilled plats and cultivated rows during several seasons, resulted in the final selection for increase and distribution of the Dakota Kursk and of the Siberian strain described in the following pages.

DESCRIPTIONS OF NEW STRAINS OF MILLET.

DAKOTA KURSK MILLET.

Dakota Kursk (A. D. I. No. 3) is the name proposed for one of the selected strains of millet which is being distributed on the northern and central Great Plains. The type is a definite one, although closely resembling in its botanical characters certain other strains of Kursk millet. The plants grow erect, or inclined when nearly ripe; the stools or culms are very numerous and small. The leaves are numerous, comparatively narrow, fine in texture, and of a distinctly lighter green than those of the other selections of Kursk millet mentioned in this bulletin. The seed head is from 2 to 4 inches long, about five-eighths of an inch thick in the middle, and tapers slightly to base and tip. It has the characteristic stiff bristles of other millets, but the head is close and firm, so that the seed does not shatter easily. The color of the seed coat of mature seeds is nearly apricot orange, as represented by Ridgway.[1]

This variety has not always ranked first among the writer's selections in respect to hay production, but it is one of the best in quality of forage and in habit of growth, and it is also one of the most productive, both of hay and of seed. (See Pl. I, fig. 1.)

SIBERIAN MILLET.

Siberian millet (A. D. I. No. 4–3) is a larger type of millet than the Dakota Kursk, and therefore produces a somewhat larger tonnage of hay under favorable moisture conditions. The plants grow fairly erect or slightly spreading. The stems are coarser and less numerous than in the Kursk variety, and often have an olive-brown coloring of the basal internodes. The leaves are broad, rather thick, and comparatively coarse. (See Pl. I, fig. 2.) The seed head is 3 to 5 inches long, cylindrical, and much less compact than in the Kursk millet, usually declined or drooping. The seeds are the same color as in Dakota Kursk, apricot orange, but the shade is paler.

The results of plat tests at Akron, Colo., and Newell, S. Dak., show that, on the average, Siberian millet (A. D. I. No. 4–3) will produce a slightly larger tonnage of hay than Dakota Kursk. The latter, however, produces a more desirable quality of hay, being finer, more leafy, and possibly more nutritious, as is indicated by the results of chemical

[1] Ridgway, Robert. Color Standards and Color Nomenclature, pl. 14. Washington, 1912.

analyses. The seed production of Dakota Kursk is also better, especially in dry seasons, than that of the Siberian strain. Under more humid conditions this millet may be the more profitable variety, but in the Great Plains it is probable that Dakota Kursk will give better average results.

COMPARATIVE YIELDS OF SELECTED STRAINS OF MILLET.

In testing the comparative value of the progeny strains of millet, two methods of planting have been used. These were (1) ordinary plats of one-tenth or one-twentieth acre in size, with the seed drilled at the rate of 20 pounds per acre, and (2) cultivated rows 8 rods long, seeded at the rate of 2 pounds per acre. In most cases the plats have been planted in duplicate or triplicate, and the rows in all tests have been planted in duplicate.

At the Akron Field Station the two varieties of millet which have given the largest yields are Siberian and Kursk. These varieties have been represented in the comparative tests by uniform strains selected for drought adaptation. The two strains of Siberian millet have given slightly higher yields than the six strains of Kursk millet, both in drilled plats (Table II) and in cultivated rows. Of the strains of Siberian millet, A. D. I. No. 4–3 is a better hay type than No. 4–5, being finer and more leafy.

TABLE II.—*Yields of millet strains in drilled plats at Akron, Colo., from 1910 to 1914, inclusive.*

Variety and number.	Yield of air-dry hay per acre (pounds).					
	1910[1]	1911[2]	1912[2]	1913[3]	1914[2]	3-year average, 1911–1913.
Dakota Kursk, A. D. I. No. 3	5,320	3,700	5,830	4,420	5,300	4,650
Dakota Kursk, A. D. I. No. 3–2		3,500	5,990	4,700		4,730
Kursk, A. D. I. No. 5	5,080	3,300	5,820	4,500	5,580	4,540
Kursk, A. D. I. No. 10	4,340	3,430	5,470	4,010		4,300
Kursk, A. D. I. No. 10–3		3,370	5,980	4,480		4,610
Kursk, A. D. I. No. 13–3		3,430	5,755	4,420		4,540
Average	4,910	3,460	5,810	4,430	5,470	4,560
Siberian, A. D. I. No. 4–3		4,220	6,020	4,580	5,710	4,940
Siberian, A. D. I. No. 4–5		4,340	6,170	4,560		5,020
Average		4,280	6,100	4,570	5,710	4,980

[1] Yields based on single plats.
[2] Yields based on the average of duplicate plats.
[3] Yields based on the average of triplicate plats.

Among the strains of Kursk millet, A. D. I. No. 3 and a selection from this strain, A. D. I. No. 3–2, have given the highest yields at Akron. (See Table II.) These two strains are practically identical in type of plant and have been given a common name, Dakota Kursk. No. 3–2 has given somewhat the greater yield, both at Akron and at Newell, and hereafter the strain bearing this number will be used as far as possible for distribution to farmers.

At the Belle Fourche station, Newell, S. Dak., in drilled plats, Siberian millet, A. D. I. No. 4–3, produced larger yields than the strains of Kursk millet in 1912 and 1914, while in 1913 the yield was about the same. In cultivated rows, the highest yielding strain in 1912 was Dakota Kursk No. 3. At the Ardmore (S. Dak.) Field Station in 1914 the Siberian strain, No. 4–3, yielded slightly higher than the Kursk strains. At the Mandan (N. Dak.) Field Station the yields of Dakota Kursk millet and Siberian No. 4–3, based on the average of triplicate plats, were exactly the same, 4,300 pounds per acre. (See Table III.)

TABLE III.—*Yields of millet hay in drilled plats at Newell, S. Dak., 1912 to 1914, inclusive, and at Ardmore, S. Dak., and Mandan, N. Dak., in 1914.*

Variety and number.	Newell, S. Dak.			Ardmore, S. Dak.	Mandan, N. Dak.
	1912 [1]	1913 [2]	1914 [2]	1914 [2]	1914 [3]
Dakota Kursk:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
A. D. I. No. 3	6,410	3,040	1,300	2,080	4,300
A. D. I. No. 3–2		3,250			
Kursk:					
A. D. I. No. 5	6,320	3,650	1,500	2,000	4,240
A. D. I. No. 10	6,400	2,950			
A. D. I. No. 13–3	6,350	3,750			
Average	6,370	3,330	1,400	2,040	4,270
Siberian, A. D. I. No. 4–3	6,850	3,300	2,000	2,170	4,300

[1] Yields based on single plats.
[2] Yields based on the average of duplicate plats.
[3] Yields based on the average of triplicate plats.

SEED PRODUCTION OF MILLET.

Millet of the foxtail type (*Chaetochloa italica*) is grown chiefly for forage, and yet some varieties, especially the Kursk, produce very good crops of seed. When millet is grown for seed in the Great Plains it is generally safest, in order to insure a crop, to plant in cultivated rows. When planted in this way Kursk millet has seldom failed to produce a profitable crop. Table IV gives a summary of the yield of seed at Akron, Colo., and Newell, S. Dak. The lowest yield recorded at Akron was in 1910, when the average from all strains of Kursk millet was at the rate of 17.8 bushels per acre. In 1912 the six Kursk strains yielded at the rate of nearly 36 bushels per acre. At Newell in 1912 five strains of Kursk millet yielded at the rate of 21.7 bushels per acre and the two strains of Siberian millet at the rate of 14.3 bushels per acre.

There is a demand from commercial seed companies for pure millet seed, and it would seem that growing this crop for seed is likely to become a profitable industry in some sections of the Great Plains. It can, no doubt, be raised more economically on the cheaper lands of the Great Plains than on the more expensive lands of the prairie region farther east. There is certainly every reason why farmers in the Great Plains should grow all the seed required for their own planting, and it is not unlikely that much of the eastern demand for millet seed can be supplied from this region.

TABLE IV.—*Seed yield of millet strains at Akron, Colo., and Newell, S. Dak., in bushels per acre.*[1]

Variety and number.	Akron.				Newell.	Average.
	1909	1910	1911	1912	1912	
Dakota Kursk:						
A. D. I. No. 3	29.5	....	32.0	28.4	24.3	28.6
A. D. I. No. 3-2	....	16.6	30.5	39.0	24.4	27.6
Kursk:						
A. D. I. No. 5	34.0	....	26.0	39.0	18.8	29.5
A. D. I. No. 10	28.5	....	31.0	36.3	17.7	28.4
A. D. I. No. 10-3	....	20.4	31.0	36.5	....	29.3
A. D. I. No. 13-3	....	16.4	23.0	35.8	23.4	24.7
Average of Kursk strains	30.7	17.8	28.9	35.8	21.7	27.0
Siberian:						
A. D. I. No. 4-3	....	24.4	20.5	37.8	15.2	24.5
A. D. I. No. 4-5	....	20.4	24.0	39.8	13.4	24.4
Average of Siberian strains	....	22.4	22.3	38.8	14.3	24.5

[1] For seed production the millets were grown in cultivated rows 3½ feet apart. Fifty pounds of seed is considered a bushel.

BREEDING SORGO FOR ADAPTATION TO DROUGHT.

In breeding sorgo [1] it has been the object to secure a type which matures early, in order that it may be grown with greater profit in the northern Great Plains, where at the present time very little sorgo is grown. The drought resistance of sorgo and its heavy forage production make it a valuable crop for the dry-land farmer, while its many varieties and types, which cross-fertilize readily and are extremely variable, offer great opportunities for the plant breeder in the improvement of the crop.

The sorgo-breeding work described in this paper was begun with an early strain of the Minnesota Amber type, known as South Dakota No. 341. The original seed of this strain was noted by Prof. W. A. Wheeler at the Highmore (S. Dak.) substation in 1903, where it was being grown under the name "Montana." The variety was extremely variable and contained a few very early and desirable types. Individual plants representing these types were selected and several more or less uniform strains were developed from these. Comparative-yield tests of these strains in cultivated rows at Newell, S. Dak., and Akron, Colo., have resulted in the selection of one of the best for increase and distribution on the northern Great Plains. This is the earliest and most distinct of the selected types and is described in this paper under the name Dakota Amber.

[1] The term "sorgo" is here used in accordance with the practice established by Mr. Carleton R. Ball (The history and distribution of sorghum, U. S. Dept. Agr., Bur. Plant Indus. Bul. 175, p. 8, 1910) to designate the saccharine as distinguished from the grain types of sorghum.

DAKOTA AMBER SORGO, A NEW FORAGE VARIETY.

The name Dakota Amber is here proposed for the strain A. D. I. No. 341–10–4, which is a selection from Minnesota Amber (S. D. No. 341). This strain of sorgo is of a distinct type and comes true when not crossed with other forms of sorghum. It most nearly resembles the Minnesota Amber type, but it is more dwarf in habit of growth and is 15 days earlier in maturing than the Minnesota Amber variety. The plants are slender, 4½ to 5 feet high, bearing 3 to 5 stems nearly equal in height; leaves 7 or 8 per stem; panicle rather compact, 5 or 6 inches long; seed oval, cinnamon color;[1] glumes black, shining, with slight hairiness at base.

This variety is valuable on account of its earliness, excellent forage, and good seed production. It will mature perfectly at the Belle Fourche Experiment Farm, Newell, S. Dak., in 90 days. This station is in latitude 44° 42′ N., and has an altitude of 2,900 feet. It is probable that this variety will mature wherever Northwestern Dent corn will ripen.

The forage, on account of the fine stems and comparative leafiness, is of excellent quality. The stems are uniform and equal in height. Each stem produces a seed head, or panicle, which makes a ripening field very uniform in appearance. The leafy character of the variety is well shown in Plate II, figures 1 and 2.

In the latitude of Kansas and Nebraska the larger types of sorgo (Red Amber, Orange, and ordinary Minnesota Amber) will, no doubt, produce larger crops than this dwarf variety (Dakota Amber). Throughout the Dakotas and Montana, however, and at higher altitudes farther south in the Great Plains, this early variety is likely to prove a valuable addition to the few forage crops grown there. The yield of this variety can be increased, where drought is not too severe, by planting somewhat thicker than is recommended for the larger varieties. Thicker planting compensates for the small size of the individual plants.

The seed production of this variety is remarkably good. Under average conditions of moisture supply it will produce from 15 to 25 bushels of seed per acre. At Akron, Colo., in 1912, under rather unfavorable conditions, the yield of seed was 14 bushels per acre, while at Newell, S. Dak., on soil that was fallow the previous season, the yield in 1913 was over 28 bushels per acre. It is an easy matter, therefore, to increase the variety and secure seed for forage planting.

In perfectly clean seed of Dakota Amber sorgo there are about 26,000 seeds per pound, but in ordinary seed, which contains a large proportion of hulls, there are about 16,000 or 18,000 seeds per pound.

[1] Ridgway, Robert. Color Standards and Color Nomenclature, pl. 29. Washington, 1912.

Allowing a germination of 75 per cent, ordinary seed will produce about one plant per linear foot of row when seeded at the rate of 1 pound per acre in rows 3½ feet apart. This dwarf form of sorgo, Dakota Amber, may be planted somewhat thicker than the larger kinds, so that 5 or more pounds per acre are recommended.

It is necessary to have sorgo nearly mature at the time of harvest, in order that the crop may have the highest possible food value. The protein and fats are present in relatively large quantity in the earlier growth of the plant, while the carbohydrates develop most rapidly in the later stages of growth. For this reason it is desirable to have a variety which will approach maturity in the region where it is grown, in order to secure the maximum food value of the crop.

TABLE V.—*Comparative yields of air-dry forage of sorgo, corn, and Sudan grass at Akron, Colo., Mandan, N. Dak., Newell, S. Dak., and Ardmore, S. Dak., from 1911 to 1914.*

[The actual yield is stated as pounds per acre; the relative yield is the ratio to that of Dakota Amber, which is taken as 100 in each case.]

Crop, variety, and strain.	Akron, Colo.						Mandan, N. Dak.	
	1911 [1]		1912 [2]		1914 [3]		1914 [3]	
	Actual.	Relative.	Actual.	Relative.	Actual.	Relative.	Actual.	Relative.
Sorgo, Dakota Amber:								
A. D. I. No. 341-10-4	5,155	100	7,480	100	5,530	100	7,570	100
Sorgo, Minnesota Amber:								
A. D. I. No. 341-2	4,600	89	8,780	117	6,880	126		
A. D. I. No. 341-13	4,420	86	6,540	87	5,860	106		
A. D. I. No. 341-5-1	5,500	107	7,850	105				
Sorgo, Red Amber	7,300	142	9,980	133	7,320	132	11,720	157
Corn, Northwestern Dent							4,210	56
Sudan grass					3,840	69	3,215	42

Crop, variety, and strain.	Newell, S. Dak.				Ardmore, S. Dak.			
	1913 [4]		1914 [2]		1913 [5]		1914 [2]	
	Actual.	Relative.	Actual.	Relative.	Actual.	Relative.	Actual.	Relative.
Sorgo, Dakota Amber:								
A. D. I. No. 341-10-4	2,150	100	3,400	100	820	100	1,670	100
Sorgo, Minnesota Amber:								
A. D. I. No. 341-2	2,770	129	4,040	119	700	85	1,660	99
A. D. I. No. 341-13	2,200	102						
A. D. I. No. 341-5-1	3,080	143						
Sorgo, Red Amber	1,500	70	3,420	101	600	73	2,600	156
Corn, Northwestern Dent	1,600	74	2,550	75			1,010	60
Sudan grass			1,570	46			890	53

[1] The average yield of duplicate plats except in the case of Red Amber Sorgo, of which only 1 plat was grown.
[2] The average yield of duplicate plats.
[3] The average yield of triplicate plats.
[4] The yields of Dakota Amber sorgo, Red Amber sorgo, and corn were secured from single plats; the yields of the three selections of Minnesota Amber sorgo from duplicate plats.
[5] The yields secured from single plats of each variety.

Another advantage in growing this early strain is the profit to the farmer in producing his own seed. Sorgo seed costs from $2 to $5 per 100 pounds [1] when bought from seedsmen, and farmers are not likely to grow a large acreage unless they can produce their own seed. There is probably a further advantage in having locally acclimated seed. This has been shown to be true of other field crops, and it will no doubt be found to be the case with sorgo.

COMPARATIVE YIELDS OF SELECTED STRAINS OF SORGO.

The strains of sorgo developed from selected individual plants of the Minnesota Amber type of sorgo were tested during several seasons in regard to their comparative forage production and drought resistance at the Akron (Colo.) and Newell (S. Dak.) stations. The principal tests were made in plats by planting in rows 3½ feet apart, cultivating between the rows. Other tests were made by planting Dakota Amber sorgo in comparison with millet and Sudan grass in drilled plats. Red Amber sorgo (commercial seed), Sudan grass, and corn (Northwestern Dent) were included for comparison in some of the tests. The results are summarized in Table V.

At Akron the larger types of sorgo, Minnesota Amber and Red Amber, have produced greater average yields of fodder than the early dwarf type, Dakota Amber. (See Table V.) In 1913 the varieties of sorgo were not weighed separately, on account of the very poor stand secured, due to drought at planting time. A half-acre plat of Dakota Amber which was grown for increase of seed yielded at the rate of 1,675 pounds per acre of air-dry forage.

At Newell the advantage also, taking the average of all yields, has been somewhat in favor of the larger types. In 1913, on plats which had produced millet the preceding year and on which the moisture supply was consequently limited, Dakota Amber (2,150 pounds per acre) yielded more than Red Amber (1,500 pounds per acre), but less than the larger type of Minnesota Amber No. 341–2 (2,770 pounds per acre). In 1914 the mean yields of Dakota Amber and of Red Amber at Newell were the same, 3,400 and 3,420 pounds per acre, respectively, while Minnesota Amber No. 341–2 made nearly 20 per cent more, or 4,040 pounds.

In spite of the larger yield of Minnesota Amber No. 341–2 there is reason to believe that Dakota Amber is the more valuable variety. It is early and will mature seed in any season, the stools are small and are easily eaten by stock, and the fodder is relatively more leafy than the larger type. Because of its smaller size Dakota Amber may be planted more thickly than the larger sorgos. This has not been done in the tests referred to, but it would probably increase the yield of this dwarf type to plant it thicker.

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[1] Three seed companies in the Northwest quoted Minnesota Amber sorgo seed in their catalogues for 1914 at $3.50, $3.75, and $6 per 100 pounds, respectively.

YIELDS OF EARLY AND LATE TYPES OF SORGO UNDER CONDITIONS OF DROUGHT.

There is no doubt that the later and larger growing varieties of sorgo will produce a greater tonnage of forage in a favorable season than the smaller forms, but in a dry season the earlier kinds are likely to produce the larger crop. The advantage of an early variety was shown at the Belle Fourche Experiment Farm in 1913, where two types of sorgo were grown under different conditions of soil moisture. The two sorgos compared were Red Amber, which is late in maturing in this locality, and Dakota Amber, a very early variety. They were grown under two conditions of soil moisture: (1) On plats which produced millet the previous season and were entirely exhausted of any stored moisture, and (2) on plats which were fallow in 1912 and were in excellent moisture condition at the time of planting. The total dry matter produced is shown in Table VI.

TABLE VI.—*Forage production of early and late types of sorgo under conditions of limited and of ample soil moisture supply at Newell, S. Dak., in 1913.*

Variety.	Air-dry forage per acre (pounds).	
	Series A; moisture limited.	Series B; moisture ample.
Red Amber (late maturing)	1,500	7,600
Dakota Amber (early maturing) No. 341-10-4	2,150	4,500

The plats which had been in millet (series A) suffered considerably from lack of moisture and were harvested August 25, 79 days after planting, the plants having by that time reached the limit of their growth. The plats which had been fallowed (series B) contained available moisture throughout the season and were harvested September 11, 96 days after planting. At this time the seeds of Dakota Amber were fully mature, while the seeds of Red Amber were in the early dough stage. Under conditions of drought the early strain produced 43 per cent more air-dry forage, but where both were enabled to approach maturity under favorable conditions of moisture the later strain produced the larger crop by 69 per cent.

COMPARATIVE YIELDS OF SORGO, MILLET, AND OTHER ANNUAL FORAGE CROPS IN THE CENTRAL AND NORTHERN GREAT PLAINS.

The farmer will desire to know which of the two crops here discussed is the more profitable under dry-land conditions and also how they compare in value with other annual forage crops which are suitable for growing in the Great Plains. Variety tests conducted in the Great Plains region by the Office of Forage-Crop Investigations of the Bureau of Plant Industry[1] have shown that the saccharine

[1] Vinall, H. N. Annual forage crops for the dry lands. *In* Jour. Amer. Soc. Agron., v. 5, no. 3, p. 176-181. 1913.

sorghums produce much the largest tonnage of any of the annual forage crops tested. The average yield of four varieties of saccharine sorghums was 3.5 tons per acre, as compared with 1.3 tons for four varieties of foxtail millets, 1 ton for cowpeas, and 0.8 ton for field peas.

From comparative yields at Akron, Colo., it appears that sorgo is a more profitable crop than millet from the standpoint of tonnage. In Table VII is given the average tonnage production of all varieties of millet in drilled plats and all sorgos in cultivated rows at Akron from 1910 to 1914, inclusive. The figures show that each year the relative yield was larger for sorgo, its average yield having been 40 per cent higher than that of millet.

TABLE VII.—*Comparative yield of millet and sorgo at Akron, Colo., in 1910, 1911, 1912, and 1914.*

Year and crop.	Number of plats, averaged.	Pounds per acre.	Relative yield.	Year and crop.	Number of plats, averaged.	Pounds per acre.	Relative yield.
1910:				1914:			
Millet	10	4,950	100	Millet	12	5,170	100
Sorgo	5	7,940	160	Sorgo	11	6,360	123
1911:				Average yield for 4 years:			
Millet	22	3,530	100	Millet		4,880	100
Sorgo	11	5,190	147	Sorgo		6,850	140
1912:							
Millet	16	5,880	100				
Sorgo	14	7,890	134				

Some idea of the relative yield of the new strains of sorgo and millet described in this paper, as compared with other types of annual forage crops, can be had from the data presented in Table VIII.

TABLE VIII.—*Yield of air-dry forage (in pounds per acre) of Dakota Amber sorgo, Red Amber sorgo, Dakota Kursk millet, Sudan grass, and Northwestern Dent corn at Newell, S. Dak., Akron, Colo., Ardmore, S. Dak., and Mandan, N. Dak.*

Location and crop.	Drilled plats.	Cultivated rows.	Average.	Relative, Dakota Amber = 100.
Newell, S. Dak., 1913:				
Dakota Amber sorgo		3,325	3,325	100
Red Amber sorgo		4,550	4,550	137
Millet	3,250		3,250	98
Sudan grass	2,650		2,650	80
Corn		2,600	2,600	78
Newell, S. Dak., 1914:				
Dakota Amber sorgo		3,400	3,400	100
Red Amber sorgo		3,420	3,420	100
Dakota Kursk millet	1,300	2,080	1,690	50
Sudan grass	2,300	1,570	1,935	57
Corn		2,560	2,560	75
Akron, Colo., 1914:				
Dakota Amber sorgo		5,530	5,530	100
Red Amber sorgo		7,320	7,320	132
Dakota Kursk millet	5,360		5,360	97
Sudan grass	4,380	3,840	4,110	74
Ardmore, S. Dak., 1914:				
Dakota Amber sorgo		1,670	1,670	100
Red Amber sorgo		2,600	2,600	156
Dakota Kursk millet	2,080		2,080	125
Sudan grass	575	890	735	44
Corn		1,010	1,010	60
Mandan, N. Dak., 1914:				
Dakota Amber sorgo		7,570	7,570	100
Red Amber sorgo		11,720	11,720	155
Dakota Kursk millet	4,300		4,300	57
Sudan grass	3,140	3,215	3,180	42
Corn		4,210	4,210	56

In comparing Dakota Amber sorgo and Dakota Kursk millet it will be seen that the results are not consistent. At Ardmore in 1914 the yield of the millet was 25 per cent greater than the sorgo, while at Newell in 1914 the millet produced only one-half as much forage as the sorgo. At Newell in 1913 and at Akron in 1914 there was a slight difference in yield in favor of the sorgo. It should be noted, however, that Dakota Amber is not as productive in seasons of favorable moisture conditions as the larger growing sorgos. The relative yield of millet is less favorable when compared with Red Amber sorgo than when compared with the smaller and earlier Dakota Amber sorgo.

Red Amber sorgo produced a greater tonnage of fodder than Dakota Amber in each of the five tests included in Table VIII. The relative yield in 1914 of Red Amber sorgo where Dakota Amber equaled 100 ranged from 100 at Newell to 156 at Ardmore. The question arises, Will it pay the farmer on the northern Great Plains to raise Dakota Amber sorgo, in view of the higher average yields of Red Amber sorgo? It has already been suggested that the yields of Dakota Amber sorgo can no doubt be increased under favorable moisture conditions by thicker planting. It has been shown that under conditions of drought Dakota Amber is likely to produce a larger crop than Red Amber. Dakota Amber will mature in a much shorter season than Red Amber and consequently can often be used as a catch crop where earlier crops have failed. It will ripen seed much farther north than Red Amber and the grower can therefore be certain of raising his own seed. These advantages of Dakota Amber sorgo seem to balance somewhat the disadvantage of lower average yields as compared with those of Red Amber.

In all the tests Sudan grass has been less productive than Dakota Amber sorgo, the relative yield where Dakota Amber equals 100 ranging from 42 at Mandan in 1914 to 80 at Newell in 1913.

Corn has produced less fodder than Dakota Amber sorgo. The relative yield at Newell in 1913 was 78, in 1914, 69; at Ardmore in 1914, 69; at Mandan in 1914, 56. The comparative yield of sorgo and corn fodder at Newell is discussed later.

It will be seen that in nearly every case the yield of sorgo is greater than that of corn, millet, or Sudan grass, and from the standpoint of tonnage alone sorgo must be considered the most desirable crop.

In comparing the yields of the three crops, millet, Sudan grass, and corn, it will be seen that in all tests except at Newell in 1914 millet has outyielded Sudan grass and corn.

COMPARATIVE YIELDS OF SORGO AND CORN FODDER AT NEWELL FROM 1908 TO 1914

The Office of Dry-Land Agriculture of the Bureau of Plant Industry has used an early strain of sorgo in its rotation experiments at the Belle Fourche station and has furnished the writer with the results of yields secured from 1908 to 1914, inclusive. The strain of sorgo used from 1908 to 1910 was of the Minnesota Amber type (S. Dak. No. 341), which is the parent stock from which the selections mentioned in this bulletin were made. In 1912, 1913, and 1914 S. Dak. No. 341–13, a selection from this strain, was used instead of the original stock. The results of yields from two closely adjacent and comparable plats of corn are given for comparison. These results are shown in Table IX.

It will be seen that where forage is the main consideration it would be much more profitable to grow sorgo than corn, for the total yield of sorgo is one-half more than that of corn. It should be considered, however, that the corn produced an average annual yield of grain of 6½ bushels per acre, which helps to compensate for the lower total weight of the crop. In most cases the sorgo also was nearly ripe when the crop was harvested and would probably have produced a yield of seed equal in value to that of the corn, although no records of the seed yield were taken.

TABLE IX.—*Comparative yield (in pounds per acre) of air-dry sorgo and corn fodder at the Belle Fourche station, Newell, S. Dak., for 1908 to 1914.*[1]

Year.	Sorgo.[2]	Corn.[2]	Relative yield of sorgo, corn=100.
1908	3,270	3,090	106
1909	5,920	3,230	183
1910	3,300	1,990	169
1912	4,100	3,870	106
1913	3,400	1,490	228
1914	1,725	725	238
Average for seven years	3,110	2,060	151

[1] No crop was planted in 1911 on account of the extreme drought of that year.
[2] Average of two rotation plats.

Corn is grown to a considerable extent in the northern Great Plains. In a favorable season a fair yield of grain is obtained, and even in a dry season some fodder will be secured. Corn is often planted for fodder alone. There is no doubt, however, that sorgo is a more profitable crop to grow where forage is the main consideration, not only on account of the higher yield of sorgo but also on account of its excellent feeding value.

WATER REQUIREMENT OF MILLET AND SORGO.

An important factor in the adaptation of millet and sorgo to conditions of drought is the low water requirement of these crops. This is a factor of special importance in the Great Plains, where the rainfall is limited and the relative water consumption of crops is in general much higher than in the more humid sections of the country. In humid regions crops are selected without regard to their water economy, but in the drier sections of the country those crops which show a low water requirement are the most likely to mature in years of deficient rainfall.

In the water-requirement measurements of Briggs and Shantz [1] at Akron, Colo., they have found that millet and sorgo are the most efficient in the use of water of any of the numerous crops compared at that place. In their summary of water-requirement determinations in 1911, 1912, and 1913 (table 34, op. cit.), the authors mentioned give the water requirement of Dakota Kursk millet (S. P. I. No. 34771) as 265 and that of Minnesota Amber sorgo (A. D. I. No. 341–13) as 305. The average water requirement of 11 varieties of corn was 368, of 7 varieties of wheat 513, and of 4 varieties of alfalfa 831. On this basis, the water required to produce 100 pounds of dry matter in Dakota Kursk millet would produce only 87 pounds of Minnesota Amber sorgo, 72 pounds of corn fodder, 52 pounds of wheat (grain and straw), and 32 pounds of alfalfa hay. The results confirm the experience of farmers, who find that sorgo and millet are among the most dependable crops grown in the Great Plains.

In 1912 the water requirement of Dakota Kursk millet was 187, being "the lowest water requirement so far recorded for any crop at Akron." In comparison with other crops this was a remarkable showing. German millet had a water requirement of 248, the proso millets 207, Red Amber sorgo 237, corn 280, Sudan grass 359, and alfalfa 659. The water required in 1912 to produce 100 pounds of Dakota Kursk millet would produce only 28 pounds of alfalfa, 52 pounds of Sudan grass, 67 pounds of corn fodder, 79 pounds of Red Amber sorgo, and 75 pounds of German millet.

WATER REQUIREMENT OF SELECTED STRAINS OF MILLET AT NEWELL.

The plant breeder who is working for increased drought resistance should determine the relative water requirement of his selected strains, as the method is a simple and comparatively rapid one and the differences, if significant, afford one of the best indications of differences in adaptability to drought conditions.

In 1912 and 1913 determinations were made of the water requirement of two strains of Kursk millet, Dakota Kursk (A. D. I. No. 3) and Kursk (A. D. I. No. 13–3), in comparison with a strain of Siberian millet (A. D. I. No. 4–3). In 1912 common millet also was included in the experiment. In 1914 only Dakota Kursk and Siberian millet (A. D. I. No. 4–3) were compared. The water requirements were as shown in Table X.

[1] Briggs, L. J., and Shantz, H. L. Relative water requirement of plants. *In* Jour. Agr. Research, v. 3, no. 1, p. 1–63, 1 fig., pl. 1–7, 1914.

TABLE X.—*The water requirement (mean of 6 pots) at Newell, S. Dak., of selected strains of millet in comparison with a commercial variety.*

Variety and number.	Water requirement.		
	1912	1913	1914
Dakota Kursk (A. D. I. No. 3)	239±3	293±3	311±11
Kursk (A. D. I. No. 13–3)	246±3	329±3	....
Siberian (A. D. I. No. 4–3)	244±4	326±2	303±7
Common millet	316±4	....	....

The results of these determinations at Newell show no consistent differences among the selected strains. The two strains of Kursk millet and Siberian millet gave the same water requirement within the limits of experimental error in 1912, but in 1913 there was a difference in favor of Dakota Kursk of 36±4 as compared with Kursk (A. D. I. No. 13–3) and 33±4 as compared with Siberian millet. In 1914 the water requirements of the two varieties measured (Dakota Kursk and Siberian, A. D. I. No. 4–3) were again practically the same. On the other hand, in 1912 all three of the selected strains had a water requirement much lower than that of common millet, a commercial variety. At Akron, Briggs and Shantz [1] found that the selected strains of millet differed in their water requirement When the entire season's growth was considered, Dakota Kursk (S. P. I. 34771) showed the lowest water requirement of the varieties and strains compared. Further comparison of the water requirement of these strains is evidently desirable.

WATER REQUIREMENT OF DAKOTA KURSK MILLET IN SOUTH DAKOTA, COLORADO, AND TEXAS.

The water requirement of Dakota Kursk millet (A. D. I. No. 3) has been measured for three years in South Dakota by the writer and in Colorado and Texas by Briggs and Shantz. The water requirement shows considerable variation, depending both upon the latitude of the locality where the measurement was made and upon the character of the season. At Newell, S. Dak. (Table XI), the water requirement was 239 in 1912, 293 in 1913, and 311 in 1914. The lowest measurement recorded was 187, at Akron, Colo., in 1912; the highest 331, at Dalhart, Tex., in 1912. The average water requirement for the three years was 256 at Akron, 281 at Newell, and 306 at Dalhart and Amarillo.

In the matter of seed production this strain of millet shows a very low water requirement. At Newell the water requirement, based on the grain, was 577 in 1912 and 661 in 1913.[2] The water requirement of Grimm alfalfa at the same place was 735 for these two years. It

[1] Briggs, L. J., and Shantz, H. L. Op. cit., p. 38, 58.

[2] At Akron in 1912, Briggs and Shantz (op. cit., p. 26) obtained the remarkably low figure of 483 for the water requirement for seed production of Dakota Kursk millet (S. P. I. 34771).

will be seen, therefore, that millet produced grain with the use of less water than was used by alfalfa in the production of hay.

TABLE XI.—*Water requirement of Dakota Kursk millet (A. D. I. No. 3) at Newell, S. Dak., Akron, Colo., and Dalhart and Amarillo, Tex.*

Place and year.	Water requirement based on—	
	Grain.	Total dry matter.
Newell, S. Dak.:		
1912	577±18	239±3
1913	661±6	293±3
1914	....	311±11
Average	....	281±4
Akron, Colo.:		
1912	483±11	187±1
1913	....	286±4
1914	1,074±38	295±2
Average	....	256±2
Dalhart, Tex.:		
1912	....	331±2
Amarillo, Tex.:		
1913	644±10	269±2
1914	1,005±19	318±4
Average	....	306±2

CONCLUSIONS.

It has been the experience of old settlers in the Great Plains that successful farming in this region must include the raising of live stock. This requires the production of forage crops under cultivation, since, except in sand-hill regions and along the watercourses, the native grasses do not grow tall enough for hay. The native "short grasses" that cover the Plains usually produce sufficient feed for summer pasturage, but cultivated crops must be depended upon for winter feeding. In the northern Great Plains certain perennial crops—alfalfa and brome-grass—give good results, but farther south the annual forage crops, millet and sorgo especially, are the most dependable. These two crops have proved to be adapted to drought and capable of producing profitable crops where the annual rainfall averages from 12 to 18 inches.

The drought adaptation of millet is due largely to its early maturity and low water requirement, while sorgo has, in addition to these two valuable characteristics, a remarkable ability to endure drought. Even though its growth is severely checked during a period of drought, it will resume growth upon the return of favorable conditions. It has been shown that millet and sorgo require less water for the production of a ton of hay than any other crops that have been tested in the central Great Plains.

The Kursk and Siberian varieties of millet have given larger yields of hay than other varieties of this crop tested in the northern Great

Plains. In each of these varieties a strain has been selected which is believed to be much superior to the parent stock. Dakota Kursk millet, one of these selections, is an early variety of good forage type. The plants are 30 to 34 inches high when mature, have many rather fine stems, and many leaves. The yield of hay from this variety has averaged 2¼ tons per acre at Akron, Colo., and 1¾ tons at Newell, S. Dak. In seed production this variety is excellent, producing under ordinary conditions from 15 to 25 bushels per acre. The seed head is close and firm and does not allow the seed to shatter readily.

Siberian millet (A. D. I. No. 4–3) is a larger type of millet than Dakota Kursk, growing from 36 to 40 inches high. It has coarser stems and leaves and makes a somewhat poorer quality of hay. It does, however, produce a larger yield per acre than the Dakota Kursk. The seed head is much larger and less firm than in the Dakota Kursk, and the seed shatters more readily. In regions of greater rainfall this variety may be more valuable than Dakota Kursk on account of its higher yield, but for the northern Great Plains it is believed that the latter variety is the better type.

A strain of early sorgo is much needed for cultivation in the northern Great Plains, where at the present time very little sorgo is grown. A strain of sorgo has been developed by selection which is especially promising for this region and for higher altitudes farther south in the Great Plains. In favorable seasons the larger growing sorgos produce a larger tonnage than this dwarf type, but in dry seasons the latter will yield at least as heavily as the larger varieties. This type is very early, maturing seed in a period of about 90 days, and can often be used as a catch crop where other crops have failed. It produces seed freely, and the farmer can easily raise his own supply of seed for forage planting. On account of the smaller size of the plants this dwarf sorgo can very well be planted thicker than the larger growing varieties. This new variety has been named Dakota Amber sorgo.

Sorgo will probably produce a larger tonnage of fodder than any other annual forage crop of this region. At Akron, Colo., sorgo has produced 40 per cent greater yields than millet. At Newell and Ardmore, S. Dak., also the results have been in favor of sorgo. In a 7-year test at Newell sorgo has produced 51 per cent more fodder than corn. Dakota Amber sorgo has produced on the average 40 per cent more forage per acre than Sudan grass in tests at Newell, Akron, Ardmore, and Mandan.

It is believed that Dakota Kursk millet and Dakota Amber sorgo will prove valuable additions to the list of forage crops adapted to the northern and central Great Plains.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 292

Contribution from the Bureau of Biological Survey
HENRY W. HENSHAW, Chief

Washington, D. C. ▼ October 25, 1915

DISTRIBUTION AND MIGRATION OF NORTH AMERICAN GULLS AND THEIR ALLIES.

By Wells W. Cooke, *Assistant Biologist.*

CONTENTS.

INTRODUCTION.

Gulls, including skuas and jægers, are represented in the United States by 22 species or subspecies and are important from several points of view. Belonging to the order of long-winged swimmers, they are strong of wing, and nearly all are coast-loving forms. They spend comparatively little of their time in fresh water; but some are true inland birds, frequenting prairies, marshes, and inland lakes.

ECONOMIC IMPORTANCE OF GULLS.

Flocks of gulls resting lightly on the waters of our harbors or following the wake of water craft are a familiar sight, but not every observer of the graceful motions of the birds is aware of the fact that gulls are the original "white wings." As sea scavengers they welcome as food dead fish, garbage, and offal of various sorts, and their

Note.—This bulletin presents precise information regarding the ranges of the several species of gulls and their allies, the skuas and jægers, especially the breeding ranges and migrations, and includes data for use for legislative reference to serve as a basis for legal protection for the species by States in which they are found. For general distribution.

services in cleaning up such material are not to be regarded lightly. It will surprise many to learn that certain gulls render important inland service, especially to agriculture. At least one species, the California gull, is extremely fond of field mice, and during an outbreak of that pest in Nevada in 1907–8 hundreds of gulls assembled in and near the devastated alfalfa fields and fed entirely on mice, thus lending the farmers material aid in their warfare against the pestiferous little rodents. The skua also feeds on mice and lemmings. Several species of gulls render valuable service to agriculture by destroying insects also, and in spring hundreds of Franklin's gulls in Wisconsin and the Dakotas follow the plowman to pick up the insect larvæ uncovered by the share.

That at least one community has not been unmindful of the substantial debt it owes the gull is attested in Salt Lake City, where stands a monument surmounted by a bronze figure of two gulls, erected by the people of that city "in grateful remembrance" of the signal service rendered by these birds at a critical time in the history of the community. For three consecutive years—1848 to 1850—black crickets by millions threatened to ruin the crops upon which depended the very lives of the settlers. Large flocks of California gulls came to the rescue and devoured vast numbers of the destructive insects, until the fields were entirely freed from them. It is no wonder that the sentiment of the people of Utah as reflected through their laws affords gulls the fullest protection. It would be well if such sentiment prevailed elsewhere throughout the United States. However, within the last few years much progress has been made in protecting these most beautiful dwellers of coasts and marshes.

BIRD REFUGES.

On March 14, 1903, President Roosevelt issued an Executive order making Pelican Island, Fla., a bird reservation—the first established in the United States. To-day there are 68 bird reservations, varying in size from a few acres to many hundred square miles. Some 27 of these, situated on the seacoast or on islands in the Great Lakes, are resorted to by gulls during the breeding season, and here these birds find safety from human molestation, while local wardens have endeavored to reduce their native wild enemies to a minimum. The 27 national bird reservations frequented by gulls are: Breton Island, Tern Islands, East Timbalier Island, and Shell Keys, La.; Passage Key and Matlacha Pass, Fla.; Huron and Siskiwit Islands, Mich.; Lake Malheur, Klamath Lake, and Three Arch Rocks, Oreg.; Flattery Rocks, Quillayute Needles, and Copalis Rock, Wash.; Chase Lake, N. Dak.; Clear Lake and the Farallon Islands, Cal.; Green Bay, Wis.; and nine reservations in Alaska.

Among the birds frequenting these reservations are the glaucous-winged, western, herring, California, and laughing gulls. Thus these reservations protect several of the most important species of North American gulls.

PROTECTION BY PRIVATE ASSOCIATIONS.

In 1900, principally through the efforts of Mr. Abbott H. Thayer, a fund of $1,400 was raised for the protection of coast birds, particularly gulls and terns, along the Atlantic from Virginia to Maine. A wardenship system was inaugurated, and 23 bird wardens were appointed the first year. The next year $1,600 was raised, 27 wardens were engaged, and the work was extended to Florida, Louisiana, and Texas. In 1902, $2,000 was donated for the protection of gulls and terns, and about 30 wardens were engaged in watching their breeding grounds. From these beginnings the work of the National Association of Audubon Societies has grown until, in 1913, over $80,000 was spent by this association for bird protection. Out of the large number of guards and wardens employed that year a considerable portion were engaged in guarding the islands and beaches along the Atlantic coast, and so extensive has the work become and so thoroughly has it been systematized that there is probably no important colony of gulls or terns throughout the whole extent of the coast from Maine to Florida that is not guarded during the breeding season. On the Gulf coast from Florida to Texas a few colonies are protected, and along the Oregon coast colonies of breeding birds are guarded by State wardens.

The results of the protection thus afforded have been most gratifying. Herring gulls along the coast of Maine have increased decidedly, while laughing gulls are beginning to be common once more in various localities where they had been almost exterminated.

LEGAL PROTECTION.

Fully as important for the protection and increase of gulls has been the enactment of State laws prohibiting their killing at any time of year and of laws prohibiting the sale of their plumage. Gulls, with their close allies, the terns, have been among the greatest sufferers from the millinery trade. As is usually the case, the birds were shot on the breeding grounds during the height of the nesting season, thus causing the death not only of the parent birds, but insuring the death of the young birds by lingering starvation. A few years ago the public awoke to the barbarity of such slaughter, and after much agitation New Jersey, in 1885, enacted the first effective State law prohibiting the killing of gulls. This example has been followed by other States until now—1915—there are 40 States which protect gulls all the year. Louisiana protects them during the breeding season, February 1 to August 1, while five States—Montana, Idaho, Nevada, Arizona, and New Mexico—offer them no protection at any time of year.

The surest way to protect any given bird is to remove the temptation to destroy it, and so the most certain way to stop the killing of gulls for the millinery trade is to prohibit the sale of gulls' wings and plumage, so that the plume hunter can find no market for his spoils. To California belongs the credit of incorporating in the game law of 1895 the first law in this country prohibiting the sale of gulls' plumage for millinery purposes. Many States followed this lead until, in 1910, New York, enacting the most drastic law of all, prohibited not only the sale but the having in possession of the plumage of any bird belonging to the same family as any of the birds of the State of New York.

DISTRIBUTION.

North American gulls and their allies include 29 species, one of which is divided into two subspecies, making a total of 30 forms. Three of these are birds of the Eastern Hemisphere which have occurred only accidentally in North America, while five others breed in the far North and are not known to occur in the United States even during migration or in winter. This leaves 22 forms of 21 species that are found in the United States. Of these, 7 both breed and winter in this country, 14 breed in the Arctic and occur here in migration or in winter, and 1 breeds south of the United States and then comes north in migration.

Old World Species Accidental in North America.

Siberian gull (*Larus affinis*). Once in Greenland.
Mew gull (*Larus canus*). Once in Labrador.
Little gull (*Larus minutus*). Once in Bermuda and once on Long Island.

Forms Breeding in the Arctic and Not Wintering in the United States.

Red-legged kittiwake (*Rissa brevirostris*). Not wintering south of the Aleutians.
Nelson's gull (*Larus nelsoni*). See note.
Slaty-backed gull (*Larus schistisagus*). Not wintering south of the Aleutians.
Vega gull (*Larus vegæ*). Not wintering south of the Aleutians.
Ross's gull (*Rhodostethia rosea*). Not wintering south of the Pribilofs.

Note.—Nelson's gull breeds in the Arctic, and, though it migrates south in winter as far as Lower California, it has not yet been taken in the United States.

Forms Breeding and Wintering in the United States.

Glaucous-winged gull (*Larus glaucescens*).
Western gull (*Larus occidentalis*).
Herring gull (*Larus argentatus*).
California gull (*Larus californicus*).
Ring-billed gull (*Larus delawarensis*).
Laughing gull (*Larus atricilla*).
Franklin's gull (*Larus franklini*).

FORMS BREEDING IN THE ARCTIC BUT OCCURRING IN THE UNITED STATES IN WINTER OR IN MIGRATION.

Skua (*Megalestris skua*).
Pomarine jæger (*Stercorarius pomarinus*).
Parasitic jæger (*Stercorarius parasiticus*).
Long-tailed jæger (*Stercorarius longicaudus*).
Ivory gull (*Pagophila alba*).
Kittiwake (*Rissa tridactyla tridactyla*).
Pacific kittiwake (*Rissa tridactyla pollicaris*).
Glaucous gull (*Larus hyperboreus*).
Iceland gull (*Larus leucopterus*).
Kumlien's gull (*Larus kumlieni*).
Great black-backed gull (*Larus marinus*).
Short-billed gull (*Larus brachyrhynchus*).
Heermann's gull (*Larus heermanni*). See note.
Bonaparte's gull (*Larus philadelphia*).
Sabine's gull (*Xema sabini*).

NOTE.—Heermann's gull breeds south of the United States and migrates north after the breeding season.

MIGRATION.

All the gulls of North America are migratory, but the distances traversed by the several species in migration vary widely. Some of them, notably Ross's gull and the red-legged kittiwake, remain near the Arctic throughout the year, and retreat southward in winter for only a few hundred miles. At the other extreme is Sabine's gull, which breeds north of the Arctic circle and winters on the coast of Peru, more than 5,000 miles away. Franklin's gull does not breed so far north as Sabine's gull, but it goes enough farther south on the coast of Chile to make its migration route fully 5,000 miles in length. Most of the gulls and their allies travel much shorter distances in their migrations, and comparatively few individuals winter as far as 2,000 miles from the breeding grounds.

Two gull-migration routes deserve special mention: Bonaparte's gull breeds about fresh water in the subarctic parts of northwestern North America, whence many individuals in fall migration travel 3,500 miles to the southeastward, reaching the Labrador coast by way of Hudson Bay before they turn southward toward their winter home on the coast of the South Atlantic States. The migration of Heermann's gull is unique among North American gulls, in that the species breeds south of the United States and at the end of the nesting season migrates north by thousands and swarms along the Pacific coast of the United States, even journeying to British Columbia. The birds remain on the California coast all winter and at the approach of the breeding season depart southward to their summer home.

ANNOTATED LIST OF SPECIES.

SKUA. *Megalestris skua* (BRÜNNICH).

The skua breeds in Iceland and on the Faroe and Shetland Islands. Though reported as breeding in North America, there seems to be no proof that it has ever nested in the Western Hemisphere, even in Greenland. The bulk of the birds winter off the coast of Europe south to Gibraltar, but the species is not rare at this season around the banks of Nova Scotia and near Georges Banks, off the Massachusetts coast.

During migration it has occurred in Greenland at Disco Island, (Figgins), Unamak (Schalow), and Ivigtut (Helms), and has been noted in the eastern part of Hudson Strait (Low); near Lady Franklin Island, north of Hudson Strait, in September (Kumlien); a few on the Grand Banks off Newfoundland, in fall (Collins); one, at Belle Isle Strait, Labrador, June 22, 1882 (Turner); Ipswich Bay,

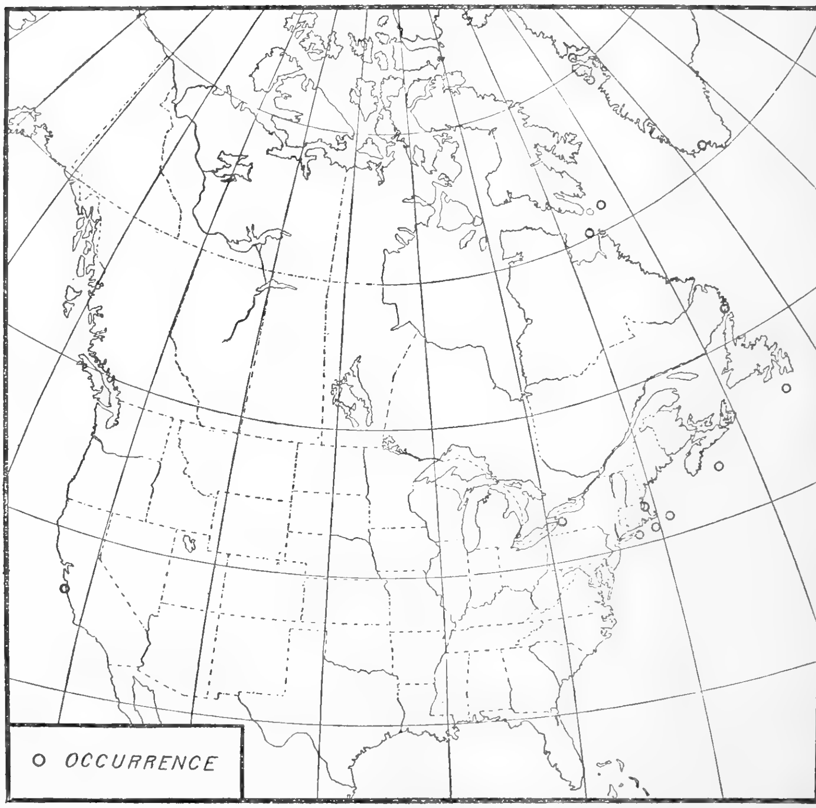

FIG. 1.—Skua (*Megalestris skua*). B2052-5

Mass., September 17, 1878 (Allen); a pair near Nantucket Island, October 17, 1883 (Collins); Woods Hole, Mass., September 19, 1889, August 30, 1889 (Edwards); Georges Banks, Mass., July, 1878 (Baird, Brewer, and Ridgway); one, Niagara River, N. Y., spring of 1886 (Bergtold); one, Montauk, N. Y., August 10, 1896 (Scott); one, near Amagansett, Long Island, N. Y., winter of 1885–86 (Dutcher); the species has wandered twice to the Pacific coast, since a specimen was taken by Colonel Pike off Monterey, Cal., many years ago, and one was taken in Monterey Bay, Cal., August 7, 1907 (Beck).

POMARINE JÆGER. *Stercorarius pomarinus* (Temminck).

Range.—Both hemispheres, from the Arctic Islands south to Australia, southern Africa, and Peru.

Breeding range.—The rarest of the three jægers is probably the pomarine jæger, which breeds in North America from North Somerset Island at Fury Point (Ross) and Upernivik on the west coast of Greenland, latitude 73° (Hagerup), south to the northern coast

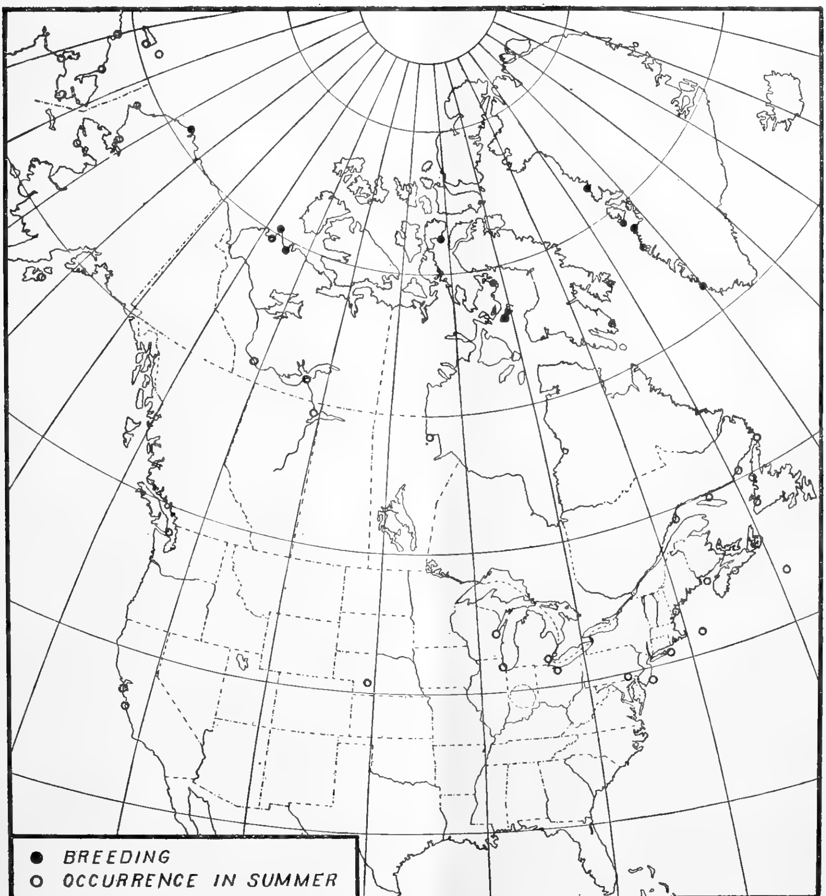

Fig. 2.—Pomarine jæger (*Stercorarius pomarinus*).

of Alaska, at Cape Lisburne (eggs in National Museum), and Point Barrow (Stone); to the coast of Mackenzie at the mouth of the Anderson River (MacFarlane), Cape Bathurst (Thayer), and Franklin Bay (MacFarlane); Igloolik (Richardson), Exeter Sound on Baffin Land (Kumlien), and on the west coast of Greenland, latitude 64° (Hagerup). It has been noted north to Melville Island (Sabine), and probably breeds there. It also breeds in the Arctic regions of the Eastern Hemisphere, where it has been noted to latitude 83°, north of Spitzbergen, but though recorded during the breeding season at numerous places from the eastern coast of Greenland to northeastern Siberia, there are few if any actual breeding records, except on the islands off the northern coast of eastern Siberia.

Winter range.—Actual winter records are almost lacking. The species has been taken south to Cape York, in Australia, Walfisch Bay in southern Africa, and Callao Bay in Peru. It seems probable that the regular winter home lies south of the Equator and that individuals recorded with more or less certainty as having occurred in winter on the Orkneys, off the coast of Massachusetts, and on the California coast are stragglers or belated migrants.

Migration range.—During spring and fall the pomarine jæger occurs as a migrant off both coasts of the United States. It is not rare at either season, but is much more common in fall, when it continues passing the coast of Massachusetts and Long Island Sound until November. As is the case with many other water birds, this species is fairly common south to the eastern end of Long Island, then as the coast turns westward, the birds continue southward out to sea and are unknown along the coast of the rest of North America or anywhere on the eastern coast of South America. Stragglers have twice been taken on the coast of New Jersey at Long Beach (Scott) and Andalusia (Vansciver). On the California coast the species is a rare migrant in spring and is common, at least near Monterey, from August to October, but it is not recorded along the coast between California and Peru.

In the interior the pomarine jæger is rare, but is more than a casual visitor to the lakes of Mackenzie. It was taken near Fremont, Nebr., in May, 1873 (Aughey), and at North Platte, Nebr., November 11, 1895 (Barnum).

Spring migration.—Dates of spring migration in the United States are almost lacking. The birds are said to pass the New England coast in May, but if so, the migration must be quite rapid, for the first arrived June 10, 1823, at Igloolik (Richardson), 2,000 miles north of Massachusetts. Dates of arrival at Point Barrow, Alaska, latitude 71°, are June 24, 1882, June 6, 1883 (Murdoch), and May 23, 1898 (Stone). A straggler was taken near Detroit, Mich., May 30, 1879 (Collins).

Eggs have been recorded at Cape Bathurst, Mackenzie, June 20, 1901 (Thayer); Cape Lisburne, Alaska, June 10, 1885 (Thayer); and Point Barrow, Alaska, June 24, 1898 (Stone).

Fall migration.—The return movement begins so early that before the young are out of the nest fall migrants are appearing many hundred miles south of the breeding grounds. These early birds must, of course, be those which did not nest or which lost their eggs or young. Some dates of fall arrival are: Peach Bottom, Lancaster County, Pa., July 4, 1869 (Barnard); near Lynn, Mass., July 5, 1889 (Tufts); Little Gull Island, Long Island, N. Y., common August 6-16, 1888 (Dutcher); Bonne Bay, Newfoundland, August 16, 1877 (Kumlien); mouth of the Churchill River, Keewatin, several July 21, 1900 (Preble); Cape Blossom, Alaska, July 1, 1899 (Grinnell); Nome, Alaska, July 14, 1908 (Thayer); Kodiak, Alaska, August 15, 1888 (Ridgway); Monterey, Cal., August 1, 1892, July 31, 1894 (Loomis); Callao, Peru, November 17, 1883 (Macfarlane).

Some late fall records are: Montauk, N. Y., October 30, 1889 (Scott); Ossining, N. Y., October 18, 1877 (Fisher); Block Island, R. I., October 11, 1895 (Howe and Sturtevant); Long Beach, N. J., December, 1876 (Scott); near Halifax, Nova Scotia, about October 4, 1869 (Gilpin); Chicago, Ill., October 9, 1876 (Nelson); Fort Simpson, Mackenzie, October 16, 1860 (Ross); Point Barrow, Alaska, September 20, 1897 (Stone); Cape Irkaipij, northeastern Siberia, September 5, 1911 (Thayer and Bangs); near Victoria, British Columbia, October 22, 1898 (Kermode); Monterey, Cal., November 11, 1896 (Loomis); and the Galapagos, December 15, 1897 (Rothschild and Hartert).

PARASITIC JÆGER. *Stercorarius parasiticus* (LINNÆUS).

Range.—Both hemispheres, from the Arctic islands south to Australia, southern Africa, and Brazil.

Breeding range.—The parasitic jæger breeds on many of the Arctic islands of the Eastern Hemisphere and south to Scotland, and from Point Barrow, Banks Land (Bay of Mercy), Melville Island (Winter Harbor), and Godhavn, Greenland, south to Kamchatka, (Bering Island) Near Islands (Agattu), Aleutians (Kiska and Amchitka), Kodiak Island, and Glacier Bay, Alaska, Great Slave Lake (Stone Island and the eastern end of the lake), to near York Factory, Keewatin, and to Hudson Strait.

Winter range.—Winter records for the parasitic jæger in the Western Hemisphere are so rare as to suggest the probability that the species does not regularly occur at that season along the coasts of either North or South America. It was taken both December 4 and June 20 at Rio Janeiro, Brazil (Saunders), but of course the June bird was an accidental straggler, unless this is really a mistake in labeling for January. A summer bird also was taken on Barbados July 10, 1888 (Feilden). These three seem to be the only certain records at any season of the year for South America and the West Indies, and there seems to be no record at any time of the year for Central America and Mexico. There are several December records for the United States, but these seem to represent late fall migrants rather than wintering birds. In the Eastern Hemisphere the species winters south along the coasts of Europe and Africa to the Cape of Good Hope, the Persian Gulf, Australia, and New Zealand.

Migration range.—In fall this jæger appears not rarely on both coasts of the United States from Maine to Florida and from Washington to southern California. It also occurs along the coast of British Columbia and the Maritime Provinces. It has been noted not rarely on the Great Lakes and several times as a wanderer in Colorado, Kansas, Nebraska, Iowa, and Missouri. Almost without

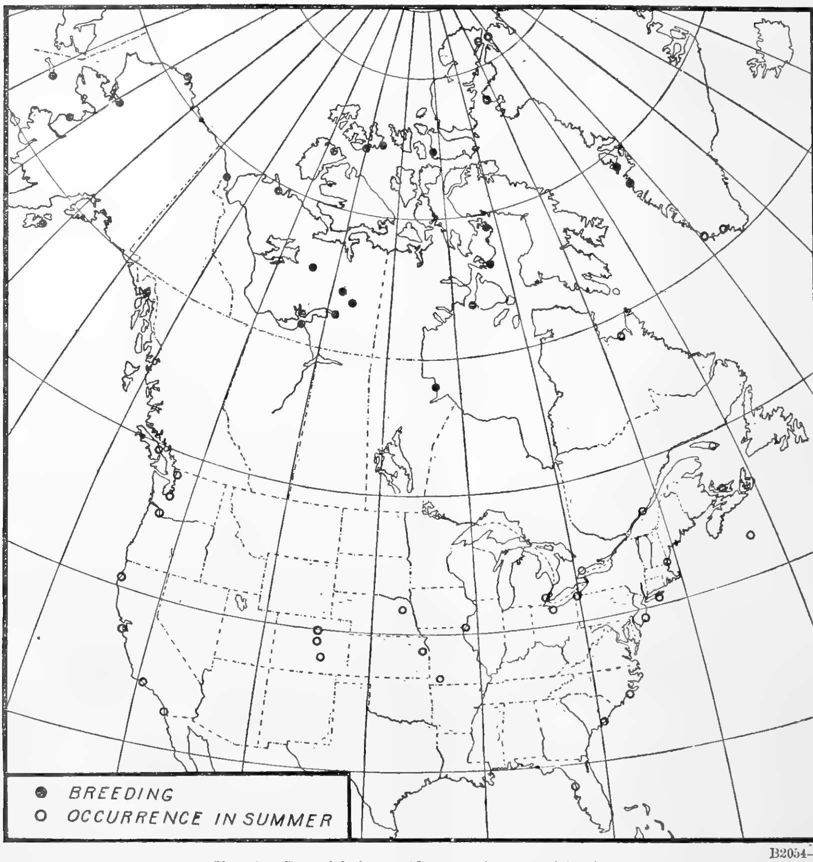

FIG. 3.—Parasitic jæger (*Stercorarius parasiticus*).

exception all these records are in fall. There are hardly half a dozen spring records for both coasts, indicating that these birds are stragglers from the regular migration routes. Those seen October 26–28, 1912, off the coast of southern Brazil (Murphy) were undoubtedly migrants on their way to a more eastern and southern winter home.

Spring migration.—As just remarked, records in spring are not common south of the breeding range. The parasitic jæger arrived at Bay of Mercy on Banks Land, May 31, 1852 (Armstrong), and was noted at Dealy Island, June 16, 1853 (M'Dougall), Fort Conger, latitude 81° 40′, June 18 and 20, 1883 (Greeley), and Thank God Harbor, about the same latitude, June 14, 1872 (Davis). The species certainly did not breed that season at Fort Conger, and probably did not at Thank God Harbor. Its regular breeding range does not seem to extend north of about latitude 75°. At Point Barrow, Alaska, the first arrived May 31, 1882, and May 29, 1883 (Murdoch), and June 1, 1898 (Stone); at Kigulik Mountains, Alaska, May 21, 1905 (Anthony); at St. Michael, Alaska, May 7, 1851 (Adams); and at Bering Island, Kamchatka, May 4, 1883 (Stejneger). Some other spring records, probably accidental, are: Stone Harbor, N. J., May 27, 1901 (Voelker); Tacoma, Wash., May 17, 1897 (Bowles); and Renovo, Pa., June 18, 1911 (Pierce).

Eggs have been secured on Bering Island, May 29, 1882 (Stejneger); Kodiak Island, Alaska, June 19, 1911 (Thayer); Kowak River, Alaska, June 20, 1899 (Grinnell); mouth of the Mackenzie River, June 27, 1894 (Russell); and on the coast of central and southern Greenland from June 4 to July 25 (Hagerup).

Fall migration.—Birds common near Cape Eskimo, Keewatin, August 4–13, 1900 (Preble), were probably in fall migration, while by this date they had already appeared much farther south at Little Gull Island, N. Y., August 6–16, 1888 (Dutcher), and at Monterey, Cal., August 1, 1892, and August 4, 1894 (Loomis). Some other fall dates are: Mingan Island, Quebec, July 20, 1881 (Brewster); Orient, Long Island, N. Y., September 13, 1907, September 12, 1909 (Latham); Sodus Bay, N. Y., August 28, 1910 (Guelf); Ottawa, Ontario, September 4, 1909 (Eifrig); Charlestown Beach, R. I., September 2, 1897 (Hathaway); Cambridge, Mass., August 30, 1901 (Eustis); Seabrook, N. H., September 2, 1897 (Allen); near Sable Island, Nova Scotia, September 9, 1878 (Allen); Comox, British Columbia, September 2, 1903 (Brooks); and Tacoma, Wash., September 17, 1896 (Bowles).

Some dates of casual or accidental occurrence in the interior are: Billings, Mo., August, 1905 (Widmann); Keokuk, Iowa, October 6, 1896 (Praeger); Eagle Lake, near Britt, Iowa, September 20, 1905 (Anderson); near Lincoln, Nebr., September 13, 1898 (Eiche); near Lawrence, Kans., October 10, 1898 (Snow); Boulder, Colo., December (Ridgway); Denver, Colo., fall of 1889 (Smith); Pueblo, Colo., fall of 1894 (Lowe). Around the Great Lakes the species has been seen at Sandusky Bay, Ohio, October 6, 1895, and September 13, 1899 (Moseley); Detroit River, Mich., November 27, 1903 (Barrows); near Dunnville, Ontario, October 16, 1886 (McIlwraith); Erie, Pa., October 15, 1874 (Sennett); North Hamlin, N. Y., November 16, 1894 (Guelf); Toronto, Ontario, June 20, 1891, and October 20, 1894 (Fleming).

The last were noted at Point Barrow, Alaska, August 27, 1882 (Murdoch), and September 9, 1897 (Stone); Port Providence, Plover Bay, Siberia, September 12, 1880 (Bean); St. Michael, Alaska, September 16, 1899 (Bishop); St. George Island, Alaska, October 18, 1913 (Hanna); Wellington Channel, latitude 75°, September 2, 1852 (McCormick); Fort Simpson, Mackenzie, October 16, 1860 (Ross); North Hamlin, N. Y., November 16, 1894 (Guelf); Comox, British Columbia, November 8, 1903 (Brooks); Bellingham Bay, Wash., October 28, 1893 (Edson); Hyperion, Los Angeles County, Cal., December 18, 1911 (Willett); San Diego, Cal., December 16, 1884 (Henshaw); Charleston, S. C., occasional in November and never seen later (Wayne)

LONG-TAILED JÆGER. *Stercorarius longicaudus* VIEILLOT.

Range.—Arctic regions of both hemispheres; south in winter to Gibraltar and Japan.

Breeding range.—Since the long-tailed jæger seems to be confined in winter to the Eastern Hemisphere and finds its principal summer home on the Arctic islands north of Europe and Asia, it is natural that it should be most common during the latter season in those parts of the Western Hemisphere which are nearest these main breeding grounds. It is an abundant breeder in northern Greenland on both coasts south to Scoresby Sound on the east and Disco Bay on the west; it is equally common on the neighboring Ellesmere Island from Cape Union on the north (Feilden) to King Oscar Land on the southwest (Sverdrup). On the western side of North America it ranges east from Siberia, breeding in Kotzebue and Norton Sounds, south to St. Michael (Nelson) and east along the Arctic coast to Franklin Bay (MacFarlane). It nested inland on the tundra near Fort Anderson, and eggs were sent to the United States National Museum, claimed to have been taken as far inland as La Pierre House, Yukon, and are in the Thayer Museum from the Caribou Hills, Mackenzie. Between these two breeding areas in North America lies a district stretching across 35 degrees of longitude, in which the species is not yet known to occur during summer.

Winter range.—It seems probable that the long-tailed jæger does not regularly winter anywhere in the Western Hemisphere. There are only two records during the winter season (from November to May), and if not mistakes in identification they must represent accidental occurrences. The winter home is in the Eastern Hemisphere, south to Gibraltar on the Atlantic side and to Japan on the Pacific.

Spring migration.—The first birds of this species arrived at St. Michael, Alaska, May 16, 1881 (Nelson); Nulato, Alaska, May 15, 1868 (specimen in U. S. National Museum); Kowak River, Alaska, May 22, 1899 (Grinnell); and at Point Barrow, Alaska, May 30, 1883

(Murdoch). On Ellesmere Island the first was noted at Cape Sabine, May 23, 1884 (Greeley); Fort Conger, June 3, 1882, and June 4, 1883 (Greeley); and at Cape Union, June 6, 1876 (Feilden).

The species is practically unknown in spring in North America south of latitude 60°. A few are reported to have visited Cumberland Gulf in June, 1878, but did not breed and soon disappeared. Two individuals are recorded as having been seen May 6, 1894, 80

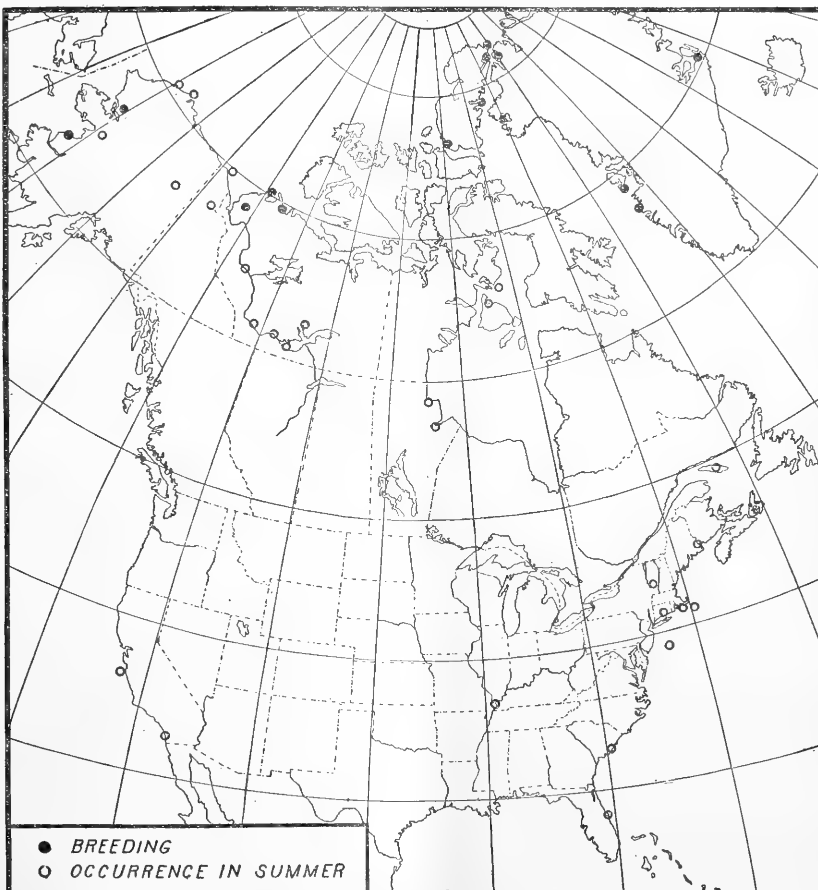

FIG. 4.—Long-tailed jæger (*Stercorarius longicaudus*).

miles offshore from Barnegat, N. J. (Chapman); these birds, if correctly identified, were 2,000 miles away from their usual habitat at that season.

Eggs were taken at Waigat Strait, near Godhavn, Greenland, June 1, 1878 (Kumlien) and also as late as July 21, 1860, near this locality (specimens in the U. S. National Museum); Baillie Island, Mackenzie, July 12, 1901 (Bodfish); Caribou Hills, Mackenzie, June 21, 1898 (Thayer); tundra east of Fort Anderson, Mackenzie, in 1865, from

June 28 to July 30, and in 1863 as early as June 26 (MacFarlane); St. Michael, Alaska, June 16, 1880 (Nelson); and at the mouth of the Kowak River, Alaska, June 17, 1899 (Grinnell).

Fall migration.—The regular disappearance of the long-tailed jæger from its breeding grounds takes place in August and September. The last was noted at Fort Conger, August 30, 1882 (Greeley), and at Point Barrow, August 12, 1883 (Murdoch). A few individuals pass south along both coasts of North America before they cross the ocean to their winter homes. On the Atlantic side they have been noted on Anticosti Island, in August, 1900 (Schmitt); West Castleton, Vt., about September 7, 1877 (Howe); Woods Hole, Mass., August 12, 1888, September 10–22, 1906, and October 13, 1894 (Edwards); on Georges Bank, off Massachusetts, not rare in fall (Collins); Monomoy Island, Mass., September 29, 1885 (Cahoon); Wallingford, Conn., August 30, 1873 (Merriam); once on Long Island, N. Y., in fall (Lawrence); and once at Cape Canaveral, Fla. (Cory). The Pacific slope records are: Okanogan Landing, British Columbia, August 30, 1905, and September 18, 1911 (Brooks); Chilliwack, British Columbia, August 23 and September 7, 1889 (Brooks); near Monterey, Cal., August 23, 1894 (Loomis); and Pacific Beach, Cal., September 19, 1904 (Bishop).

The species has occurred casually in the interior at San Sault Rapid, Mackenzie, June 19, 1904 (Preble); near Winnipeg, Manitoba, September, 1896 (Seton), and October 8, 1902 (Atkinson); Southampton Island, Keewatin, August 17, 1821 (Saunders); near Cairo, Ill., November, 1876 (Ridgway); and at Lone Tree, near Iowa City, Iowa, June 15, 1907 (Anderson).

IVORY GULL. *Pagophila alba* (GUNNERUS).

Range.—Arctic seas, wintering in high latitudes in the Eastern Hemisphere south to France.

Breeding range.—The principal summer home of the ivory gull includes the Arctic islands of the Eastern Hemisphere. Here it is abundant, in many places outnumbering all other gulls combined, and has been noted north to latitude 85°. It is abundant also as a breeder in the extreme northwestern part of Greenland, from Thank God Harbor (Bessels) to Rensselaer Bay (Kane), throughout Ellesmere Island, and south to the northern part of Baffin Land at Port Bowen (Parry). To the westward it is much less common but has been found breeding west to Winter Harbor (Parry) and to the northeastern part of Prince Patrick Island (M'Clintock).

Winter range.—In the Eastern Hemisphere the ivory gull winters just to the southward of its summer home, and ranges thence south to France. It withdraws almost entirely at this season from the Western Hemisphere, except for an occasional bird that remains near the south end of Greenland, or that wanders to the eastern coast of Canada.

Spring migration.—The first ivory gull arrived at Winter Harbor, May 24, 1820 (Parry), and on the northern coast of Prince Patrick Island, June 12, 1853 (M'Clintock). One appeared at Peterman Fiord, near the northeast point of Ellesmere Island, May 28, 1876 (Feilden). It appears to be not rare in migration at Point Barrow, Alaska, where

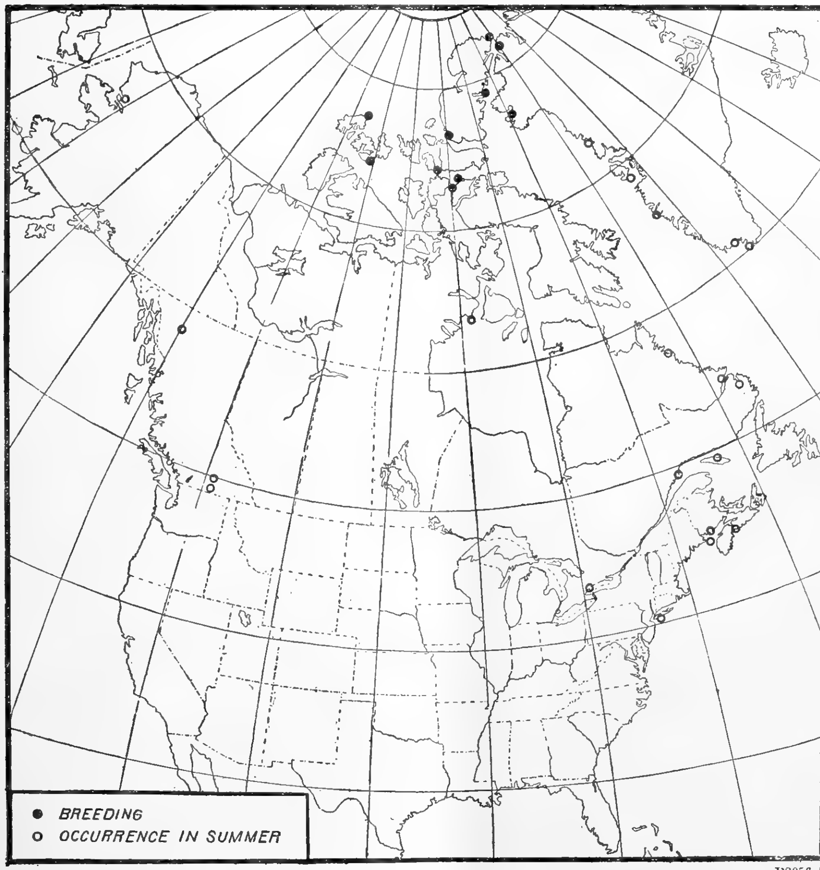

Fig. 5.—Ivory gull (*Pagophila alba*).

it was noted May 22, 1882 (Murdoch), and June 2, 1898 (Stone). Stragglers have been recorded from Godbout, Quebec, April, 1877, and March 7, 1906 (Comeau), and Sandwich Bay, Labrador, June 12, 1897 (Dawson), while one of the few records for the Pribilof Islands, Alaska, is that of a specimen taken on St. Paul Island in the early spring of 1895 (Prentiss).

The earliest eggs were found June 21, 1853, on Prince Patrick Island (M'Clintock), and the nesting season is so extended that eggs have been secured the first week in August on both Spitzbergen (Bendire) and Franz Josef Land (Johnson).

Fall migration.—In 1850 the last ivory gull was seen near Wellington Channel, September 15 (Kane). Two years later none were seen there after September 5 (McCormick), while the last had been noted at Boothia Felix, September 21, 1829 (Ross). Near the northern limit of its range, at Lincoln Bay, Ellesmere Island, the last disappeared September 1, 1875 (Feilden), but 10 degrees farther south, at Point Barrow, Alaska, the species was seen until October 10, 1882 (Murdoch), and to September 25, 1897 (Stone). A few were still present November 9, 1912, in Bering Strait, between East Cape and the Diomede Islands (Thayer and Bangs), and on Bering Island, December 2, 1875 (specimen in U. S. National Museum).

Individuals wander south along the Atlantic Coast of North America and a few have been captured at Okak, Labrador (Weiz); Rigolet, Labrador (Dawson); Anticosti Island, October, 1902 (Schmitt); Godbout, Quebec, December 9, 1895, and January 5, 1908 (Comeau); Halifax, Nova Scotia (Jones); St. John, New Brunswick, November, 1880 (Brewster); Grand Manan, New Brunswick (Boardman); Penobscot Bay, Me., December, 1894 (specimen in U. S. National Museum); Lake Ontario (McIlwraith); Monomoy Island, Mass., December 1, 1886 (Allen); and Sayville, Long Island, N. Y., January 5, 1893 (Dutcher). The species has been noted once on the Kowak River, Alaska (McLenegan), once on St. George Island, Alaska (specimen in U. S. National Museum), and three times in British Columbia: Dease Lake, September, 1889 (Kermode); Penticton, October, 1897 (Brooks); and Okanogan Lake, November, 1897 (Kermode).

KITTIWAKE. *Rissa tridactyla tridactyla* (LINNÆUS).

Range.—Arctic America, east of the Mackenzie; Arctic Europe and western Siberia; south to northern Africa, the Canaries, Bermuda, and New Jersey; casual in the interior of eastern North America.

Breeding range.—The kittiwake breeds as far north as it can find solid land on which to put its nest, and it has been noted over the ice packs even to latitude 84° 52′ (Sverdrup). It is circumpolar and almost everywhere that observations have been made on the Arctic islands, this species has been recorded as nesting abundantly. In the Western Hemisphere it was found breeding north to Thank God Harbor, Greenland (Bessels); Cape Union, Ellesmere Island (Feilden); north of Wellington Channel, latitude 77° (Belcher); Winter Harbor, Melville Island (Parry); Point Barrow (Stone); and the whole length of the coast of northwestern Alaska north of Bering Strait and of northeastern Siberia.

The above represents the range of the species as a whole. The dividing line between the eastern (typical) subspecies *tridactyla* and the western *pollicaris* has not yet been determined. It is known that the western form extends east to Point Barrow, but since Murdoch did not observe the bird there, and Seale did not see it east of Icy Cape, it is probable that it is rare at Point Barrow, and that this marks about the limit of the eastern extension of its range. If many nested east of Point Barrow, then the birds would probably be common there in fall migration, since they are strictly confined to the seacoast. East of Point Barrow for 30 degrees of longitude there are no records of kittiwakes of any form nor was one recorded by any of the explorers who visited Banks Land and Prince Patrick Island. Though seen by Richardson at Franklin Bay, in 1826, it was not included in the enormous collections made by MacFarlane in this same region 40 years later; showing that if it occurs there at all at present it must be very rare. The above statements seem to warrant the belief that the western subspecies *pollicaris* is restricted to the region west of Point Barrow, and that all the birds on the Arctic islands of North America belong to the eastern subspecies *tridactyla.*

The subspecies *tridactyla* breeds south to the mainland of northern Asia, to northwestern France, the southern end of Greenland (Hagerup), Magdalen Islands (Brewster), Godbout, Quebec (Comeau), Cape Fullerton (Low), and Franklin Bay, Mackenzie (Richardson).

Winter range.—The birds breeding north of Europe and eastern Siberia range southward in winter to the shores of the Caspian Sea, to the southern coast of the Mediterranean, and to the Canaries (Saunders). The breeding birds of the Western Hemisphere desert the Arctic islands during winter, but are common at this season among the outer islands on the Maine coast (Knight), at Grand Manan, New Brunswick (Herrick), and at least as far north as Halifax, Nova Scotia (Jones). The species remains in the Gulf of St. Lawrence around Prince Edward Island as long as it can find open water, and undoubtedly it often stays all winter.

The whole New England coast is visited during winter, as well as Long Island Sound and the New Jersey coast south to Long Branch and Atlantic City (Stone). The kittiwake wanders still farther south and was noted February 4, 1913, off the coast of Maryland, latitude 37° 46′ N., longitude 74° 10′ W. It is not rare on Bermuda, having been seen from January 5 to April 4 (Reid), and in January, 1901, all the way on the ocean from New York City to latitude 25° 51′ N., longitude 37° 43′ W., several hundred miles southeast of Bermuda.

Migration range.—The kittiwake is normally a salt-water species, but it ascends the St. Lawrence regularly to Quebec and rarely to Montreal (Dionne). It has wandered inland to Enosburg Falls, Vt., November 12, 1906 (Woodworth); Oak Orchard, Orleans County,

N. Y., April 10, 1881 (Bruce); Auburn, N. Y., January 4, 1854 (Hopkins); Oneida Lake, N. Y., November 9, 1890 (Bagg); Lancaster, Pa., once, winter (Warren); Erie, Pa., October 17, 1900 (Todd); Toronto, Ontario, one, October 31, 1899, and several in November of that year (Fleming); Chicago, Ill., December 9, 1896 (Woodruff); Neebish Island, Mich., once, taken in fall (Boies)—in fact, it is probable that

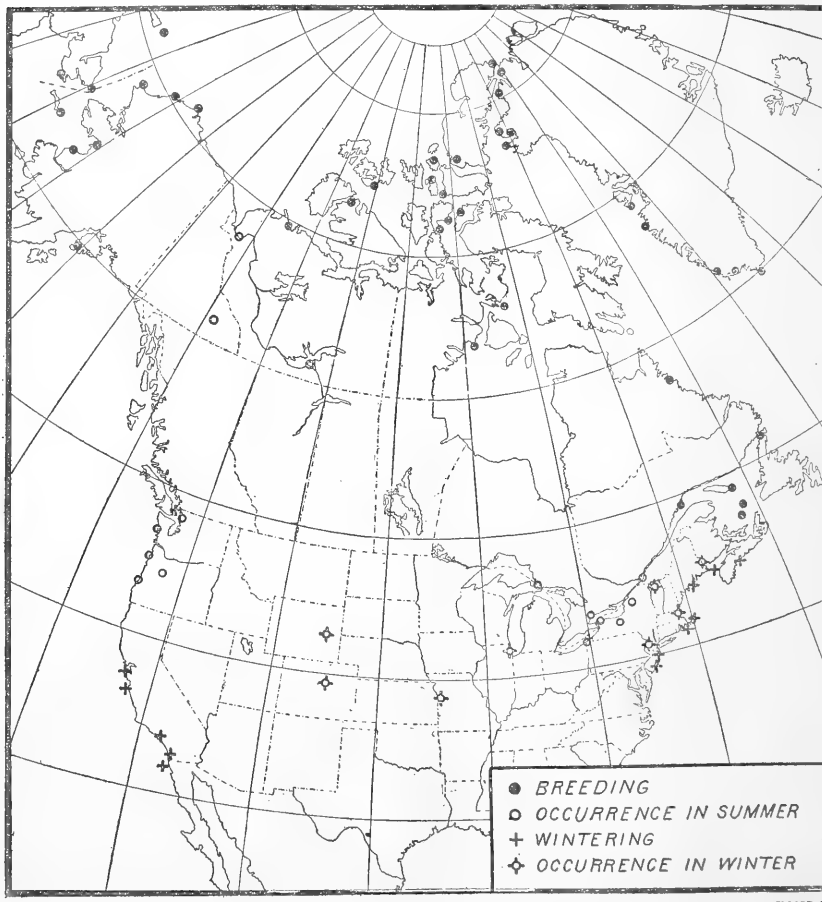

FIG. 6.—Kittiwake (*Rissa tridactyla*). Typical subspecies (*tridactyla*) ranges west to the Rocky Mountains; Pacific subspecies (*pollicaris*) is found on the western and northwestern coasts.

each fall and winter finds some individuals around the Great Lakes; near Kansas City, Mo., once, in 1897 (Widmann); Arctic Red River, Mackenzie, October 5, 1910 (Thayer); Fort Simpson, Mackenzie, May 15, 1860 (Ross); Douglas, Wyo., November 18, 1898 (Jesurun); and Boulder, Colo., one in December (Ridgway).

Spring migration.—Just north of the winter home, the first kittiwakes arrived at North River, Prince Edward Island, on the average, March 26, earliest March 15, 1891; Godbout, Quebec, average April 6, earliest March 25, 1884, and the mouth of Great Whale River, Quebec, March 26, 1899 (Eifrig). With such an early start the northward progress is not fast and it is June before the first arrive in the northern part of the range—Cape Farewell, Greenland, June 7, 1821 (Parry); Cape York, Greenland, June 10, 1825 (Parry); Fort Conger, Ellesmere Island, June 21, 1885 (Greeley); Prince of Wales Strait, June 7, 1851 (Armstrong); and north of Wellington Channel, latitude 77°, June 19, 1853 (Belcher). In 1887 the first arrived at Ivigtut, Greenland, on March 26 (Hagerup).

The southern part of the winter home is deserted early in the season and the last bird is reported to remain on Long Island to March 17 (Dutcher); New Haven, Conn., April 14 (Merriam); Newport, R. I., March 23, 1900 (Mearns), and Gloucester, Mass., March 13, 1890 (White). A few remain on the coast of Maine all summer and have been reported at White Horse Ledge, in Jericho Bay, July 11, 1903; and near Portland, July 14, 1907 (Norton). The species was noted June 5–11, 1894, on Sable Island, Nova Scotia (Dwight). In none of these cases did these summer birds show signs of breeding, and they were undoubtedly barren.

Eggs of the kittiwake were taken on the Bird Rocks near the Magdalen Islands, June 10, 1877 (specimens in U. S. National Museum), and July 10, 1855, on the west coast of Greenland, latitude 76° (Kane). Exceptionally early eggs were found at Ivigtut, Greenland, June 1, 1887 (Hagerup).

Fall migration.—A few migrants appear in southern Maine early in fall—Piper Pond, August 4, 1901 (Ritchie), and Islesboro, August 14, 1907 (Knight)—but these may be nonbreeding birds that have spent the summer not far to the northward. The main body of the migrants does not appear until much later. Many years' observations on the Massachusetts coast give November 6 as the average date of arrival, earliest October 27, 1890. The earliest date on Long Island is November 4 (Braislin).

Ice drives the kittiwake from the Arctic in early fall and in 1852 the last was seen at Wellington Channel, September 2 (McCormick), and September 1, 1876, at Lincoln Bay, Ellesmere Island, latitude 80° (Feilden).

PACIFIC KITTIWAKE. *Rissa tridactyla pollicaris* RIDGWAY.

Range.—Coasts of the North Pacific, Bering Sea, and the adjacent Arctic Ocean.

Breeding range.—The Pacific kittiwake replaces the eastern subspecies, *tridactyla*, in the North Pacific and neighboring parts of the Arctic Ocean. It breeds north to Herald Island (Nelson), Cape Lisburne (Stone), Icy Cape (Seale), and Point Barrow (Stone), though it is not common east of Cape Lisburne, and its presence at Point Barrow may be more or less casual. It breeds south to Seldovia, Alaska (Chapman), and the Shumagin Islands, Alaska (Dall), while a specimen taken at Yakutat, Alaska, June 21, 1899, and now in the U. S. National Museum, indicates that the subspecies may breed in that locality.

It is abundant on the eastern Aleutians, but much less common west of Unimak Pass, though it was not rare on Kiska Island, June 17–21, 1911 (Wetmore), and occurs on the Near Islands (Turner). On the Asiatic side it is abundant on the Commander Islands (Stejneger) and breeds south to the Kurils (Saunders). It breeds on the Arctic coast of Siberia west to Koliutschin Islands, and ranges west to Chaun Bay (Thayer and Bangs).

Winter range.—The Pacific kittiwake is commonly believed to winter in the Aleutians, but there seems to be no certain record of its occurrence there at that season. It does winter at Sitka, Alaska (Willett), and on the coast of southern British Columbia—Discovery Island, January, 1896 (Kermode)—and thence south along the coast regularly to central California, and occasionally to southern California and northern Lower California: Paso Robles, March 31, 1913, (Thompson); Playa del Ray, January 9, 1906, and December 30, 1911 (Willett); Alamitos Bay, April 14, 1907 (Linton); San Diego, February 26, 1895 (Anthony); San Geronimo Island, Lower California, March 15, 1897 (Kaeding). Kittiwakes are probably more common during winter along the coasts of northern California, Oregon, and Washington than is indicated by the scant half dozen records for this long coast.

On the Asiatic side there seem to be no winter records farther south than the southern limit of the breeding range on the Kurile Islands, indicating that these most southerly breeding kittiwakes are nonmigratory. The more northern breeders retire so far to the southward that they do not winter on the Commander Islands (Stejneger).

Spring migration.—The first kittiwakes arrived at St. Paul Island, Pribilofs, April 20, 1909 (Island log), and April 24, 1911 (Hanna); at St. Michael, Alaska, May 6, 1851 (Adams); and Point Barrow, Alaska, June 2, 1898 (Stone). The first were noted in 1883 on Bering Island about April 1 (Stejneger).

Eggs were taken at Walrus Island in Bristol Bay, Alaska, June 8, 1889, and at Cape Lisburne, June 10, 1885 (specimens in U. S. National Museum). The nesting season is much prolonged, for eggs were obtained at Seldovia as late as July 24, 1903 (Chapman), and on St. Paul Island to August 2, 1890 (specimens in U. S. National Museum).

Kittiwakes were last seen at Point Pinos, Cal., April 25, 1907 (Beck); and they were still present at Port Townsend, Wash., May 19, 1911

(Wetmore), and at Campbell Island, British Columbia, May 24, 1911 (Wetmore).

Fall migration.—Throughout the entire summer kittiwakes in adult plumage are present at Sitka, Alaska, in large numbers, but they do not nest (Willett). Several hundred were seen at Glacier Bay, Alaska, July 13, 1907 (Grinnell), including some immature birds which undoubtedly had been raised farther west or northwest and were already on their fall migration. The first were seen at Queen Charlotte Islands, British Columbia, in September, 1895 (Fannin), but it is not until November that the species reaches California. The average date of arrival at Point Pinos is November 14, earliest November 6, 1907 (Beck).

The last one noted at Point Barrow, Alaska, was on August 31, 1897 (Stone); Nome, Alaska, September 10, 1910 (Thayer); Plover Bay, Siberia, September 17, 1880 (Bean); Unalaska Island, October 5–6, 1899 (Bishop); St. Paul Island, October 12, 1914 (Hanna); and on Koliutschin Island, Siberia, September 22. 1912 (Thayer and Bangs).

RED-LEGGED KITTIWAKE. *Rissa brevirostris* (Bruch).

Range. Coasts and islands of Bering Sea.

The red-legged kittiwake breeds abundantly on the Pribilof Islands (Coinde), the Near Islands (Turner), and also on the Com-

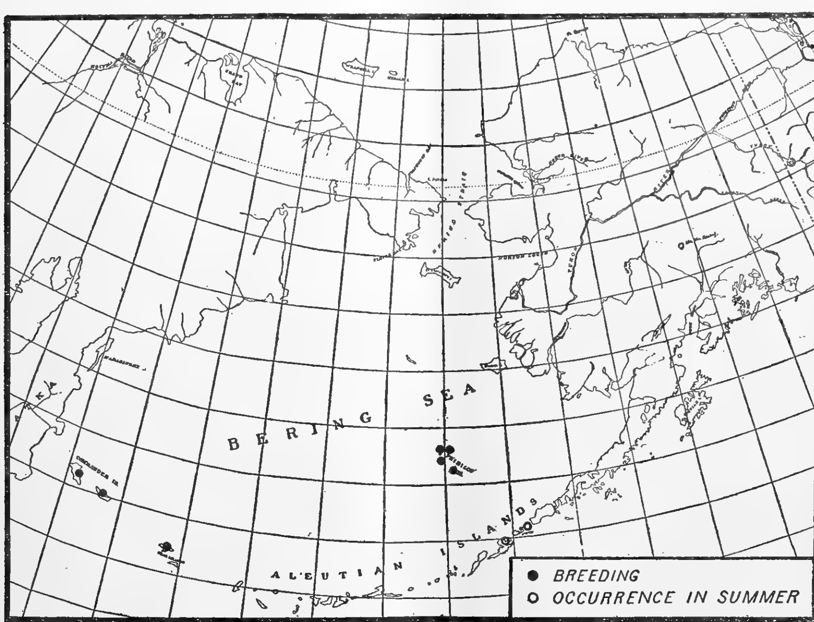

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Fig. 7.—Red-legged kittiwake (*Rissa brevirostris*).

mander Islands (Stejneger). It was common on St. Paul Island, Pribilofs, April 30, 1911 (Hahn), and eggs have been taken on St.

George Island, Pribilofs, June 25, 1873 (specimens in U. S. National Museum). It also breeds so late that young were still in the nest on St. George Island, August 31, 1913 (Hanna). In fall the species was noted at Unimak Pass (Seale), and one bird was seen October 5, 1899, on the north side of Unalaska at Dutch Harbor (Bishop). The last was noted on St. George Island November 11, 1913 (Hanna).

There is apparently no winter record for the species. Turner says that it breeds on the Near Islands but does not winter there, while Stejneger records its return to the Commander Islands about the first of April.

A straggler was taken at Forty-Mile, Yukon, October 12, 1899 (Grinnell).

GLAUCOUS GULL. *Larus hyperboreus* Gunnerus.

Range.—Arctic regions, south to California, the Great Lakes, Long Island (New York), the Mediterranean, Black and Caspian Seas, and Japan.

Breeding range.—The glaucous gull, or burgomaster, as it is commonly called by sailors, is a truly circumpolar species; wherever man has collected in the Arctic he has found this bird. It breeds on all the Arctic islands of the Eastern Hemisphere, and in the Western Hemisphere breeds north to Thank God Harbor, Greenland (Hall)—occurs north to Cape Union (Feilden), but not known to breed—King Oscar Land (Sverdrup), Prince Patrick Island (M'Clintock), Point Barrow, Alaska (Murdock), and the Chukchi Peninsula (Schalow).

It breeds south along the Labrador coast to Hopedale (Townsend and Allen) and most likely even farther south, for it breeds not rarely in Newfoundland south to Bay of Islands (Arnold). It is quite common on the east coast of Hudson Bay south to the mouth of Great Whale River and even in James Bay (Macoun), while it seems to be absent in summer from the west coast south of Fullerton (Low). It breeds along the Arctic coast from Cambridge Bay (Collinson), to Franklin Bay (MacFarlane) and Herschel Island (Thayer), and is a common breeder on the northern shores of Bering Sea south to the mouth of the Yukon (Nelson), to the Kuskoquim (Hinckley), to the Pribilofs (specimen in U. S. National Museum), and to Indian Point, Siberia (Thayer).

Winter range.—The breeding and wintering ranges of the glaucous gull overlap, since the species winters as far north as Ivigtut, Greenland (Hagerup), and Cape Mercy, Baffin Land (Kumlien), and thence south along the Atlantic coast regularly to Long Island (Peavey), rarely to the Great Lakes, and on the Pacific coast from the Aleutians south to Monterey, Cal. (Breninger). In the Eastern Hemisphere it winters south to the Mediterranean, Black, and Caspian Seas and to Japan. The few individuals that inhabit the shores of the

Pacific Ocean during the winter season apparently do not go south of California and Japan.

Migration range.—Outside of the regular winter range the species has been noted at Cape Lookout, N. C., April 3, 1897 (Coues); Bermuda, one large flock in March, 1901, and present until April 28, 1901 (Verrill); Erie, Pa., February 22, 1898 (Simpson); Ossining, N. Y., January 19, 1889 (Richardson); Buffalo, N. Y., January 29, 1895 (Savage); Millers, Ind., August 8, 1897 (Woodruff); Ottawa, Ontario, December 2, 1905 (Eifrig); Kingston, Ontario, November

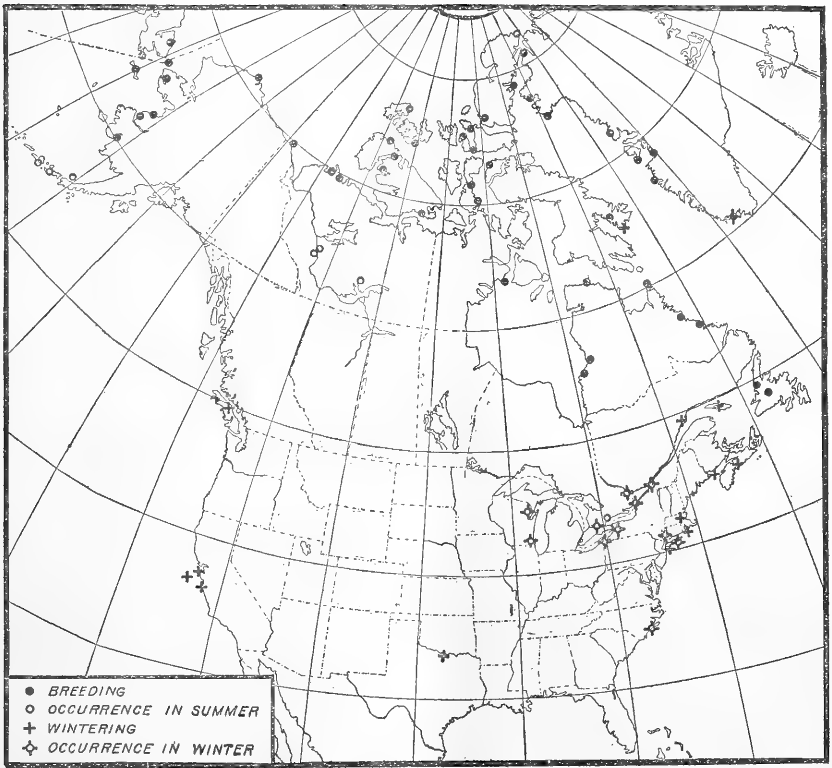

FIG. 8.—Glaucous gull (*Larus hyperboreus*).

16, 1905 (Beaupré); London, Ontario, February 1, 1906 (Saunders); Lake Ontario, common in winter, December 8 to March 25, 1889 (McIlwraith); Milwaukee, Wis., January 8, 12, and 14, 1895 (Kumlien and Hollister); Racine, Wis. (Hoy); Kelley Brook, Wis., one, December, 1890 (Schoenebeck); Red River, Clay County, Tex., December 17, 1880 (Ragsdale).

Spring migration.—The first glaucous gulls were noted at Kingwah Fiord, Baffin Land, April 20, 1878 (Kumlien), though the species had wintered on the open water not far distant. At the southern end of Greenland, where it also wintered, the numbers were augmented by the arrival of migrants as early as March 20, 1887 (Hagerup). Toward the northern limit of the range, the date of arrival is much later: Polaris House, May 10, 1873 (Davis); Rennselaer Bay, May 22, 1854 (Kane); Fort Conger, May 14, 1882, and June 5, 1883 (Greeley); Whitsunfiord, King Oscar Land, May 27, 1901 (Sverdrup); Bay of Mercy, May 31, 1852 (Armstrong); Winter Harbor, June 3, 1820 (Parry); near Wellington Channel, latitude 76°, May 16, 1851 (Sutherland); Yukon Delta, Alaska, May 13, 1879 (Nelson); Kowak River, Alaska, May 11, 1899 (Grinnell); and Point Barrow, Alaska, May 11, 1882 (Murdoch).

Some late spring dates south of the breeding range are: Rockaway, Long Island, May 1, 1904 (Peavey); Boston, Mass, April 23, 1906 (Remick); Peaks Island, near Portland, Me., April 27, 1883 (Knight); Godbout, Quebec, April 29, 1882 (Comeau); and Monterey, Cal., May 4, 1897 (Loomis); while several were seen at Unimak Pass, Aleutian Islands, June 4, 1911, and at Unalaska Harbor five days later (Wetmore), but there were no indications of breeding.

At Kingwah Fiord, Baffin Land, the first signs of nest building were noted May 24, 1878, and the first eggs were found June 8 (Kumlien). Eggs were taken at Ivigtut, Greenland, from May 10 to June 14 (Hagerup); Beechey Island, June 21, 1853 (McCormick); Cape Sabine, June 17, 1900 (Thayer); Yukon Delta, June 4, 1879 (Nelson); Kowak River, Alaska, May 26, 1899 (Grinnell); incubated eggs, in the Kolyma Delta, Siberia, June 26, 1912 (Thayer and Bangs); eggs ready to hatch, in King Oscar Land, June 24, 1901 (Sverdrup); young in the nest, at Cape York, July 2, 1858 (M'Clintock); and young just hatched, on Hall Island, Alaska, July 14, 1899 (specimen in U. S. National Museum).

Fall migration.—Birds on Amak Island, Aleutians, July 18, 1911 (Thayer), may have been either nonbreeders that had remained through the summer or the van of the fall migrants. At Anticosti Island, only a short distance south of the breeding range, the first migrants usually appear in August (Schmitt). The southern part of the winter range is not reached until much later: Fresh Pond, Mass., November 29, 1899 (Brewster); Orient, Long Island, November 30, 1909 (Latham); Boston, Mass., December 15, 1909 (Wright); Far Rockaway, Long Island, January 1, 1891 (Howell); Comox, British Columbia, December 15, 1903 (Brooks); and Monterey, Cal., November 6, 1893 (Breninger), and December 11, 1894 (Loomis).

Long before this the ice has driven the glaucous gull from most of its northern nesting grounds; the last were seen at Cape Union, Ellesmere Island, September 1, 1875 (Feilden); Thank God Harbor, September 3, 1871 (Hall); Winter Harbor, September 6, 1819 (Parry); Wellington Channel, September 5, 1852 (McCormick); Stordalen, King Oscar Land, September 11, 1899 (Sverdrup); Bowdoin Bay, Greenland, September 9, 1896, and October 17, 1893 (Clarke); Fort Rae, Mackenzie, September 30, 1893 (Russell); Roche Trempe-l'eau, Mackenzie, October 9, 1903 (Preble); Point Barrow, Alaska, November 1, 1882 (Murdoch); Kowak River, Alaska, October 13, 1898 (Grinnell); Unalaska Island, Alaska, November 12, 1904 (Thayer); St. Paul Island, Pribilofs, December 13, 1914, and February 18, 1915 (Hanna); and Diomede Islands, in Bering Strait, December 7, 1912 (Thayer and Bangs).

ICELAND GULL. *Larus leucopterus* FABER.

Range.—North Atlantic Ocean and contiguous parts of Arctic Ocean, south to the British Isles and Massachusetts.

The Iceland gull, though an Arctic species, ranges over only a small part of the Arctic regions. It occurs regularly from longitude 90° W. at Boothia Peninsula to longitude 10° W. at Jan Mayen. It is recorded as having occurred on Nova Zembla, longitude 60° E. (Smirnow). The center of its abundance is the west coast of Greenland, where it is a common breeder from the southern end at Ivigtut (Hagerup) to about latitude 70° (Schalow), though it was found at Northumberland Island, latitude 77° 30′ (Bessels), and stragglers were noted at Fort Conger, latitude 81° 40′, May 19, 1882, and June 5, 1883 (Greely), but the species does not breed there. Westward it ranges to Bellot Strait (Walker), Felix Harbor (Ross), and Cambridge Bay (Collinson). It has been taken on the east coast of Greenland north to Sabine Island, latitude 74° (Schalow), and is a not rare breeder on Jan Mayen.

Eggs were taken at Ivigtut from May 14 to June 10 (Hagerup); at Claushavn, June 20, 1878 (Kumlien); and at Christianshaab (specimens in U. S. National Museum).

This gull winters in small numbers on the southern coast of Greenland (Hagerup), and the great bulk of individuals, particularly the fully adult birds, remain at this season around northern waters from Iceland and the Faroe Islands to the British Isles, while immature birds have wandered south to Scandinavia, the Baltic Sea, and even to the Bay of Biscay.

On the American side of the Atlantic Ocean the Iceland gull comes south in winter as far as Massachusetts, Long Island, and the Great Lakes, though it is never common, and the individuals ranging so far south are principally immature birds. It has been recorded along the coast at Godbout, Quebec, February to May 1 (Comeau); Perleys Mills, Me., January 12, 1898 (Knight); near Boston, Mass., November 4, 1897 (Lothrop), December 11, 1897 (Brewster), January 15, 1894, and January 31, 1880 (Bangs), and February 11, 1894 (Jeffries); Rockaway Beach, Long Island, February 6, 1898 (Peavey); and Rye, N. Y., March 3, 1894 (Porter).

Inland it has been noted near Brockport, N. Y., September 10, 1899 (Bruce); Lansingburg, N. Y., November 21, 1888 (Eaton); Oswego, N. Y., December 28, 1899, (Miller); Peterboro, N. Y., Feb-

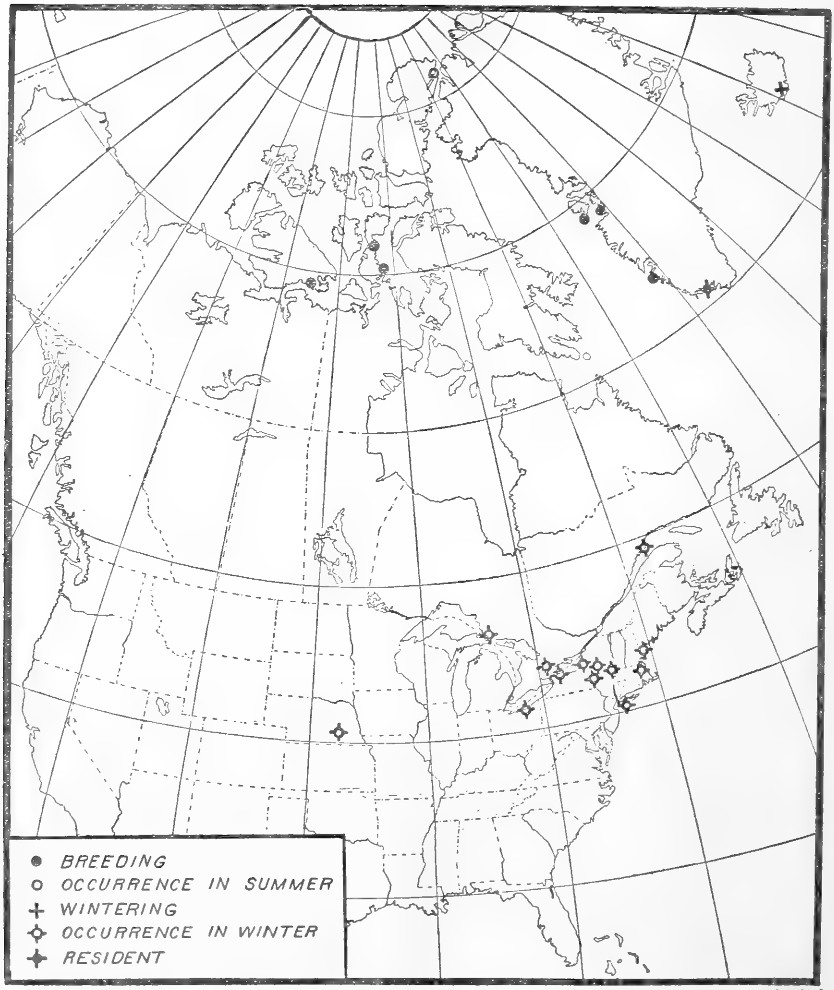

FIG. 9.—Iceland gull (*Larus leucopterus*).

ruary 1, 1884 (Lawrence); Ithaca, N. Y., March 17, 1897 (Fuertes); Rochester, N. Y., April 14, 1904 (Eaton); Lorain, Ohio, December 22, 1888 (McCormick); Toronto, Ontario, December 12, 1898 (Ames); Port Sydney, Ontario, April 6, 1898 (Fleming); Sault Ste. Marie, Mich., (Barrows); and Dorchester, Nebr., January 15, 1907 (Swenk).

GLAUCOUS-WINGED GULL. *Larus glaucescens* Naumann.

Range.—Coasts of the North Pacific, Bering Sea, and the adjacent Arctic Ocean, south to Lower California and Japan.

Breeding range.—The center of abundance of the glaucous-winged

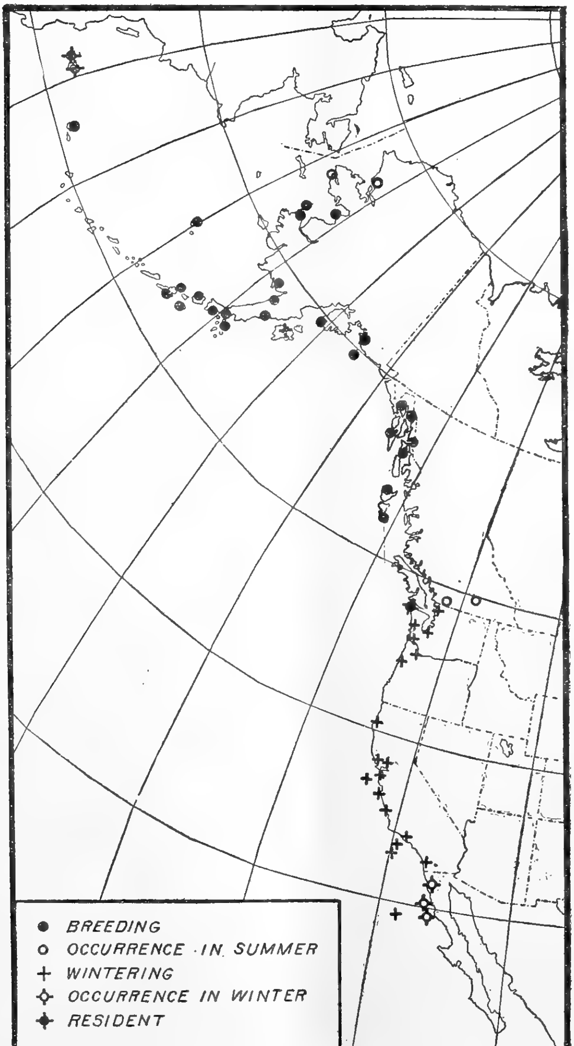

Fig. 10.—Glaucous-winged gull (*Larus glaucescens*).

gull during the breeding season is the Aleutian Islands, where it is the most abundant of gulls nesting throughout the whole chain, including the Near Islands (Turner) and the Pribilofs (Lucas). It nests also on the Commander Islands (Stejneger) and north to St. Michael and Cape Denbigh (McGregor). A single bird was seen at

Port Clarence, July 24, 1897 (Stone), another, September 6 (Bean), and one at the mouth of the Kowak River, May 11, 1899 (Grinnell). It is not probable that the species breeds anywhere north of Bering Strait. It is a common breeder on the southern coast of Alaska, the whole coast of British Columbia, and south to Destruction Island, Wash. (Jones).

Winter range.—It winters on Kodiak Island and the Pribilofs, Alaska, and probably some individuals remain at this season on the Aleutians, as they do on the Commander Islands. On the Asiatic side the species winters south to Japan, and on the American side south to Guadalupe Island, Lower California (Kaeding). It is a common winter resident along the United States coast from northern Washington to southern California.

Spring migration.—This gull was found fairly common on San Martin, Todos Santos, and San Geronimo Islands, Lower California, March 10–15, 1897 (Kaeding), and on Guadalupe Island, March 22, 1897 (Kaeding). It remained at Santa Cruz Island, Cal., until May 2, 1911 (Howell and Van Rossem), and at Monterey until May 10, 1907 (Beck). An immature bird was noted July 4, 1910, at Hyperion, Los Angeles County, Cal., but it must then have been far south of the place where hatched.

Eggs were taken June 8, 1907, off Cape Johnson, Wash. (Thayer); Carroll Island, Wash., June 19, 1908 (Jones); Mittlenatch Island, Strait of Georgia, B. C., June 18, 1896 (Dawson); Sitka, Alaska, June 16 to August 4, 1896 (Grinnell); Chico Island and Round Island in Akutan Pass, Alaska, June 2, 1872 (Dall); Walrus Island, Pribilofs, June 13, 1890 (specimens in U. S. National Museum); Bering Island, June 8, 1882 (Stejneger), Ariz Kamen, May 16, 1883 (Stejneger); Houston Stewart Channel, Queen Charlotte Islands (just hatching), July 3, 1900 (Osgood); and young, near Seldovia, Alaska, July 11, 1903 (Chapman).

Fall migration.—The first of these gulls was seen at Monterey, Cal., October 30, 1896 (Loomis), and the species was fairly common by November 12. In 1906, the first came to Monterey October 25, (Beck), and, in 1884, to Ventura, November 19 (Evermann).

Inland the species appeared at Chilliwack, British Columbia, August 26, 1889, and was last noted November 28, 1888 (Brooks), and has also been observed at Okanogan Lake, British Columbia (Brooks). Several cases are known of its following ships all the way from the California coast to Hawaii.

KUMLIEN'S GULL. *Larus kumlieni* Brewster.

Little is known of the distribution or migratory movements of Kumlien's gull. The type was taken June 14, 1878, on Cumberland Sound, where the species nested commonly (Kumlien). It had arrived as soon as open water appeared and full-grown young were common there the first days of September. A large extension of the known range was made in 1900 when eggs were taken on June 15, at Weyprecht Island, latitude 79°, on the east coast of Ellesmere Island (Thayer), and on July 1 a specimen was taken a few miles farther south, at Alexander Haven (Thayer).

In winter the species comes south along the Atlantic coast as far as Long Island, near Rockaway Beach, March 8, 1898 (Braislin);

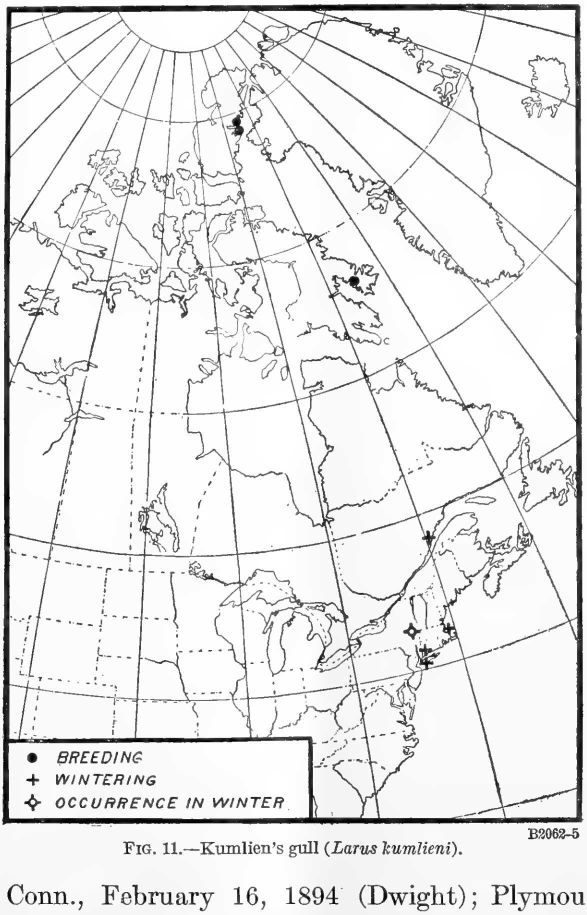

FIG. 11.—Kumlien's gull (*Larus kumlieni*).

Stamford, Conn., February 16, 1894 (Dwight); Plymouth, Mass., January 5, 1888 (Dwight); Moon Island, Boston Harbor, Mass., February 22, 1905 (Allen); Tadousac, Quebec, probably in the spring of 1901 (Dwight); near Grand Manan, New Brunswick, about January 21, 1883 (Merrill); one in the Bay of Fundy, about November 1, 1881 (Brewster); and one on Prince Edward Island, October 7, 1905 (Mac Swain). Inland, one was taken at the mouth of the Mohawk River, N. Y., January 28, 1884 (Brewster).

NELSON'S GULL. *Larus nelsoni* HENSHAW.

A single specimen of Nelson's gull, taken by Nelson at St. Michael, Alaska, June 20, 1880, served as the basis for the description of this gull. A specimen in the British Museum, taken many years previously on the coast of Alaska near Bering Strait by Captain Kellett and Lieutenant Wood, also belongs to this species. No more specimens were obtained for 17 years, until in 1897 two were taken at widely separated localities. One was secured at San Geronimo Island, Lower California, March 18, 1897 (Dwight), and one at Point Barrow, September 5, 1897 (Stone). No further specimens have been recorded in the last 18 years, though during this period active collecting has taken place at many localities along the Alaskan coast from northern British Columbia to Point Barrow.

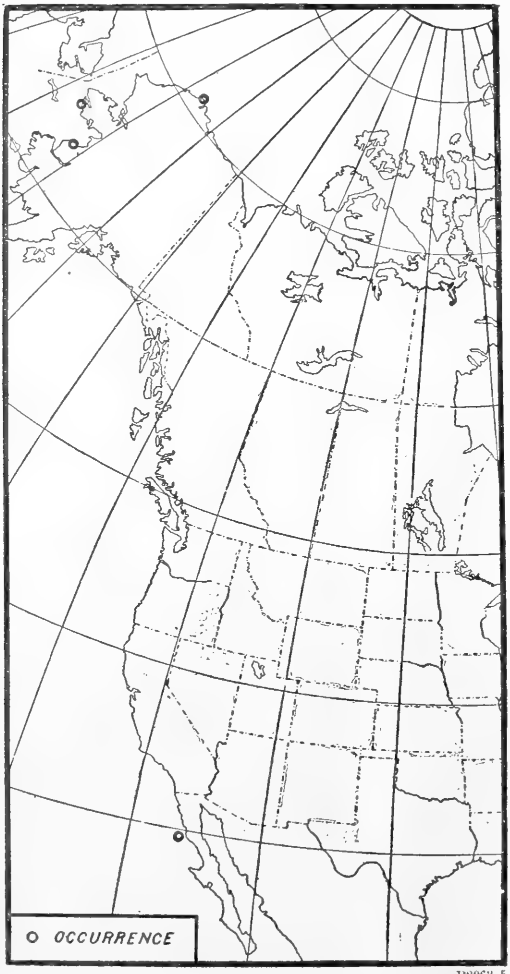

FIG. 12.—Nelson's gull (*Larus nelsoni*).

GREAT BLACK-BACKED GULL. *Larus marinus* LINNÆUS.

Range.—North Atlantic from central Greenland and northern coast of Europe, south to the Great Lakes, Delaware Bay, the Canaries, and northern Egypt.

Breeding range.—The usual northern limit of nesting of the great black-backed gull is in central Greenland, about latitude 70°, Disco (Dawson), and Godhavn (M'Clintock), but occasionally a few breed north to latitude 73° at Upernivik (Schalow), whence it breeds south to the southern end of Greenland on the west side. There seems to be no certain record of its breeding on the east coast of Greenland or anywhere on the Arctic islands of North America. It breeds along the northern coast of Europe east to the Petchora River (Saunders), but is rare on the islands off the coast; it also breeds on Iceland and south along the western coast of Europe to about latitude 50°. The principal summer home seems to be the Labrador coast, where it is an abundant breeder from Cape Chidley, Hudson Strait (Low), along the whole coast and south to Newfound-

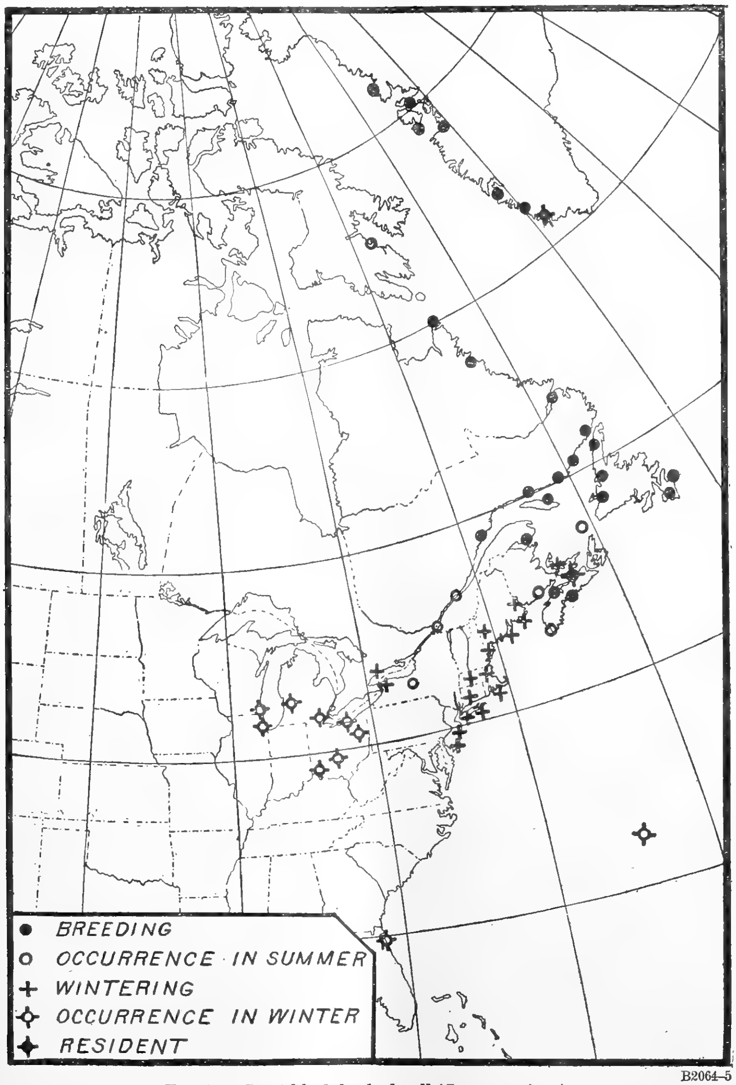

FIG. 13.—Great black-backed gull (*Larus marinus*).

land (Arnold), Anticosti Island (Brewster), Godbout, Quebec (Comeau), Pictou, Nova Scotia (Hickman), Halifax, Nova Scotia (Jones), and Kentville, Nova Scotia (Tufts). A few nonbreeders remain all summer on the Maine coast (Knight).

Winter range.—A few of these gulls winter as far north as southern Greenland (Hagerup), but the bulk are found along the United States coast from Maine to New Jersey. Some remained at North River, Prince Edward Island, all of the winter of 1888–89 (Bain), but usually they are forced away by the ice. A few visit the Great Lakes in winter. The European birds winter on inland waters and occur along the coast south to the Canaries; they also stray rarely south to Egypt. The winter of 1894–95 one wandered to St. Augustine, Fla. (Cory), and the species has been taken twice on Bermuda, December, 1851, and December 27, 1862 (Reid). It was noted at Columbus, Ohio, December 16, 1907 (Jones), and near Detroit, Mich., in March, 1904 (Swales). How nearly some individuals are nonmigratory is shown by the fact that a young bird banded July 27, 1912, in Yarmouth County, Nova Scotia, was found December 6, 1912, in Cumberland County, Me., while another one banded at the same place July 23, 1912, had moved only a few miles to the next county by December 18, 1912 (Cleaves).

Spring migration.—The first great black-backed gull was noted April 25, 1887, and April 18, 1888, at North River, Prince Edward Island (Bain); at Romaine, Labrador, March 26, 1914 (Birdseye); and at Rigolet, Labrador, April 9, 1914 (Birdseye). At St. Johns, Newfoundland, the species was present as early as March 1, 1883 (Merriam).

It was noted at Atlantic City, N. J., to March 13, 1888 (Rhoads); Orient, Long Island, to March 24, 1909 (Latham); Shelter Island, Long Island, April 12, 1893 (Worthington); Branchport, N. Y., April 18, 1898 (Stone); Boston, Mass., average, April 10 (Wright). Some unusually late individuals were seen at Toronto, Ontario, May 26, 1897 (Fleming); Rockaway, Long Island, May 13, 1910 (Griscom and Dow); Boston, Mass., May 25, 1907 (Wright); and at Woods Hole, Mass., May 30, 1893, and June 10, 1891 (Edwards). Those seen July 27, 1908, at Portland, Me. (Eastman), and July 9, 1887, at the Magdalen Islands (Bishop) may have been nonbreeding birds that had summered, or early fall migrants.

Eggs have been taken at Ivigtut, Greenland, from May 3 to June 15 (Hagerup); near Kentville, Nova Scotia, May 22–25 (Bishop); and at Godbout, Quebec, as late as July 17, 1882 (Comeau).

Fall migration.—The average date of arrival in fall at Woods Hole, Mass., is October 8, earliest September 24, 1895 (Edwards); the average at Boston, Mass., October 14, earliest October 7, 1909 (Wright); and the average at Orient, Long Island, October 5, earliest September 12, 1906 (Latham). A very early individual was seen near Cambridge, Mass., August 29, 1901 (Eustis); one near Jones Inlet, Long Island, August 14, 1910 (Weber); and at Toronto, Ontario, September

18, 1896 (Fleming). The species becomes common in its winter home about the middle of November.

The last one in 1892 at Gothaab, Greenland, was seen on September 3 (Stone); North River, Prince Edward Island, November 12, 1889 (Bain); and Pictou, Nova Scotia, December 13, 1894 (Hickman).

SLATY-BACKED GULL. *Larus schistisagus* STEJNEGER.

The principal summer home of the slaty-backed gull is on the northern shore of the Sea of Okhotsk, the eastern coast of Kam-

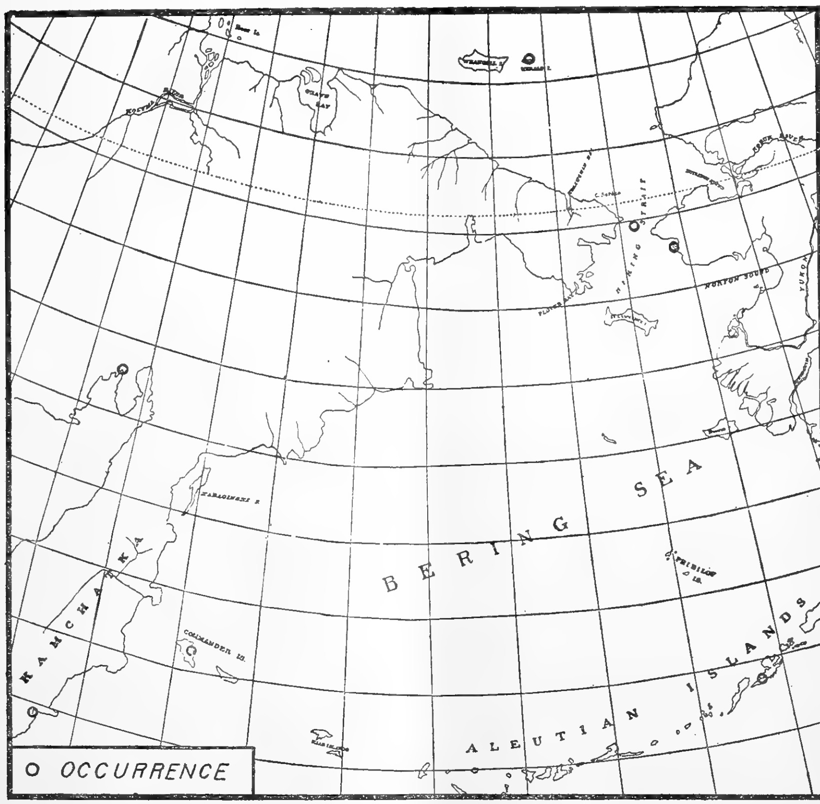

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FIG. 14.—Slaty-backed gull (*Larus schistisagus*).

chatka, and on the Kuril Islands. Here it arrives about April 20; the height of its nesting season is June 1–10, and it leaves for its winter home the middle of October, while a few remain to the last of that month. On Bering Island, where it does not breed, it arrived April 20, 1883, and remained until May 5 (Stejneger). It winters to southern Japan.

It has wandered to Herald Island in the Arctic Ocean (Ridgway); Diomede Islands in Bering Strait, September, 1880 (Hooper); Port

Clarence (Ridgway), where single birds were noted; and to Chernoffsky Bay, Unalaska, where a large flock was seen October 1, 1880 (Bean). None of these places is far distant from the usual home of the species, and it probably occurs not rarely in migration on the shores of Bering Sea and of the adjacent Arctic Ocean. A specimen taken June 9, 1901, at Franklin Bay, Mackenzie (Babbitt), was a straggler far from home.

WESTERN GULL.

Larus occidentalis Audubon.

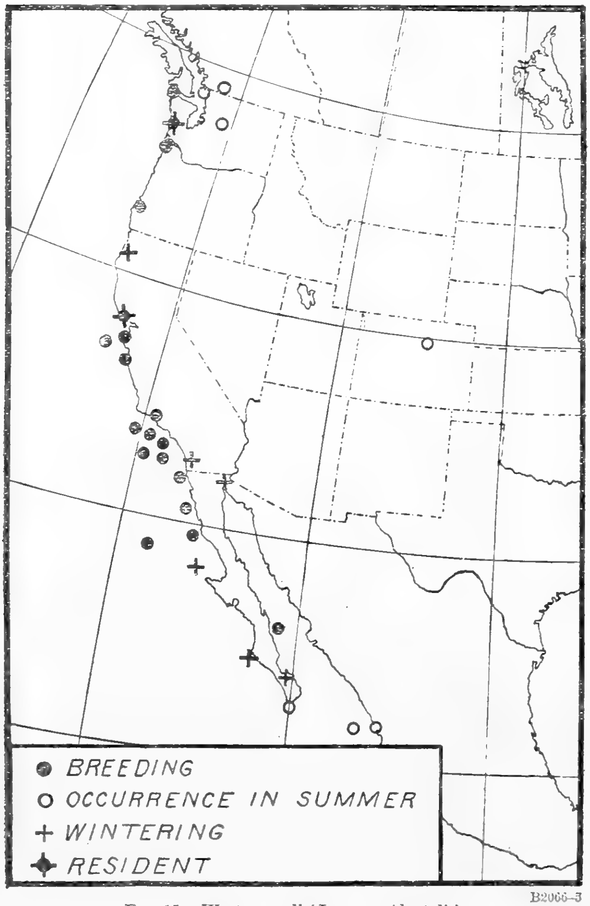

Fig. 15.—Western gull (*Larus occidentalis*).

The western gull is resident along the Pacific coast from northern Washington to southern Lower California. The species breeds north at least to Carroll Islet, Wash. (Jones), and one was seen at Tatoosh Island, Wash., June 5, 1907 (Jones), but it may have been a nonbreeder. Southward it breeds to the southern end of Lower California, near Carmen Island (Frazar). During the spring of 1905 it was common along the coast of the mainland of Mexico south to San Blas, Tepic (Bailey), and, though as late as April 6–12 it was still common on Isabella Island, one of the Tres Marias, there was no sign of its breeding anywhere in that region (Bailey).

Eggs were taken March 13, 1887, near Carmen Island, Lower California (Frazar); Idlefonso Island, Lower California, April 5–7, 1906 (Thayer); in California on the Farallon Islands, May 6, 1863, and May 13, 1864 (Cooper); May 9, 1885, May 9, 1886, and May 13, 1887 (Bryant); Santa Barbara Island, May 18, 1897 (Grinnell); and

Tomales Point, May 24, 1884 (specimens in U. S. National Museum). Eggs and young were found at Otter Rock, Oreg., June 29, 1899

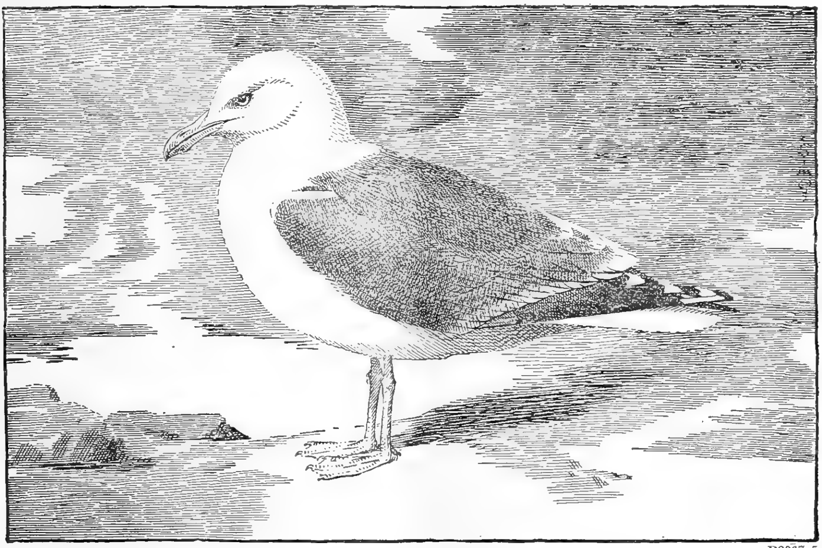

FIG. 16.—Western gull (*Larus occidentalis*), adult in summer plumage. B2067–5

(Prill), and on the islands near Lapush, Wash., June 21, 1897 (Young). The species winters commonly in Shoalwater Bay, Wash., and is not rare at this season north to Vancouver Island, British Columbia (Mayne). It also winters along the whole Pacific coast of the United States and Lower California and was abundant at the head of the Gulf of California, November 25 to December 15, 1898 (Price), and February and March, 1905 (Stone).

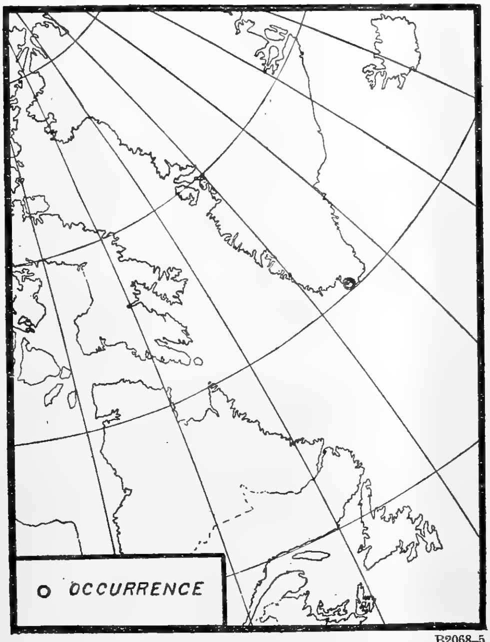

FIG. 17.—Siberian gull (*Larus affinis*). B2068–5

The species was taken once at Socorro Island, Mexico (Anthony), and once, September 30, 1889, at Loveland, Colo. (Osburn).

[SIBERIAN GULL.

Larus affinis REINHARDT.

Though normally an inhabitant of the Eastern Hemisphere, the Siberian gull was originally described from a wanderer to Nenortalik, in the Julianehaab district of southwestern Greenland. This species breeds regularly in northern Russia and Siberia from the Dwina to the Yenesei, and winters south to western India and northern Africa.]

HERRING GULL. *Larus argentatus* PONTOPPIDAN.

Range.—Northern Hemisphere from the Arctic islands of North America east to the White Sea, and south to the Caspian and Mediterranean Seas, the Gulf of Mexico, and western Texas.

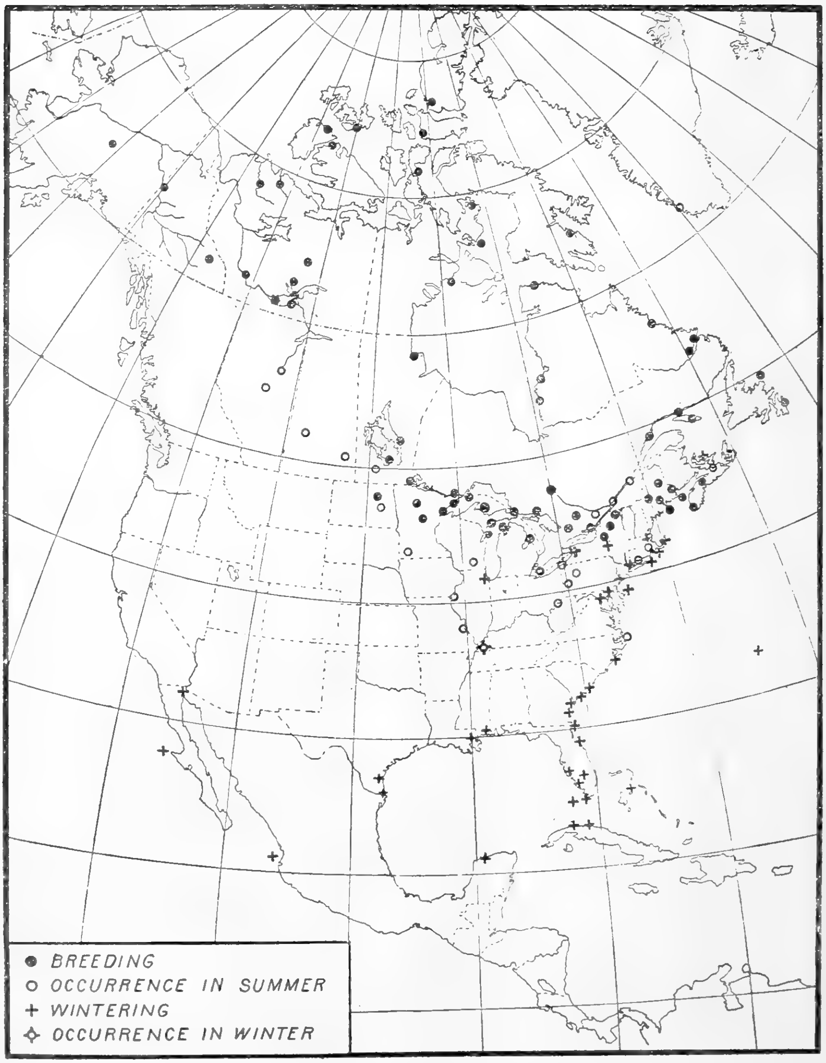

FIG. 18.—Herring gull (*Larus argentatus*).

Breeding range.—The herring gull, or silvery gull as it was called by the early Arctic explorers, breeds far north on the western Arctic islands to Melville Island (Parry), Wellington Channel (McCormick), and King Oscar Land (Sverdrup); these are in latitude about 75°, but thence eastward the breeding range turns south, and the species is not known to breed anywhere in Greenland nor on the islands north of Europe. It has wandered once to Jan Mayen (Schalow), to Frederickshaab, Greenland (Walker), and to a few other places on the west coast of Greenland (Schalow). In northwestern North America there seems to be no sure breeding record north of near Mount McKinley (Sheldon), and the middle Yukon (Dall).

The breeding range extends south to Babine Lake, British Columbia; Shoal Lake, Manitoba; Mille Lacs, Minn. (Roberts); the islands in Lake Michigan at the mouth of Green Bay (Van Winkle); the Sisters and Strawberry Island in Green Bay, Wis. (Palmer); Little Charity Island, Saginaw Bay, Mich. (Wood and Gaige); the lakes of southern Ontario (Clarke); near Wilmurt, N. Y. (eggs in U. S.

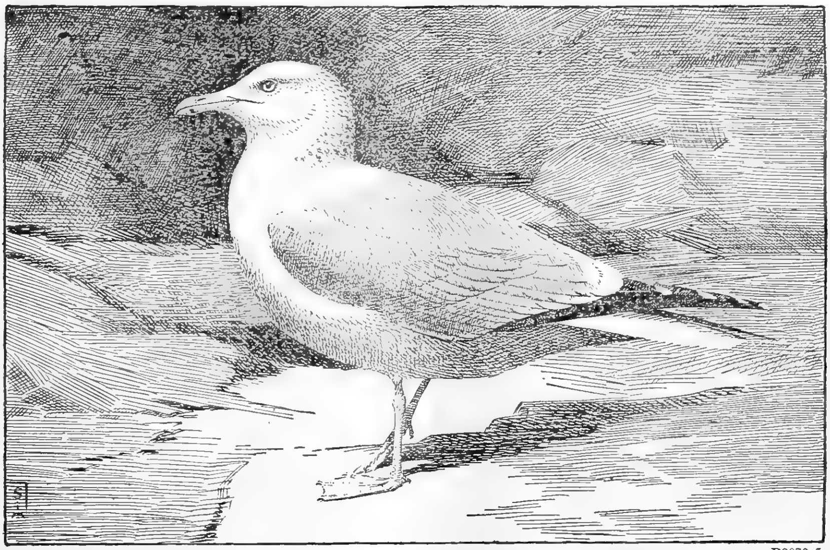

Fig. 19.—Herring gull (*Larus argentatus*), adult in winter plumage. B2070-5

National Museum); Four Brothers, Lake Champlain (Jordan); on the outer islands of the Maine coast west to No Mans Land Island in Penobscot Bay (Knight); and in Nova Scotia south to Kentville (Bishop).

In Europe the species breeds east to the White Sea and south to northern France (Saunders).

Winter range.—A few herring gulls sometimes remain in the Gulf of St. Lawrence all through the winter, as they did at North River, Prince Edward Island, the winter of 1888–89 (Bain), and at this season they are abundant on the Maine coast and southward. In the interior they are common on all the Great Lakes until the ice forms; many remain through the winter on Lake Erie, and some even on Lake Superior. On the Pacific coast the species winters north to northern Washington.

It ranges commonly in winter to the Gulf coast from Florida to Texas, less commonly to Lake Okechobee (Phelps) and Key West (Scott). A few were noted on the north coast of Cuba at Cardenas and Matanzas Bay, and the species was once found in the market at Habana (Gundlach); once, in 1888, near Nassau, Bahamas (Cory); and a few in Bermuda, November 4 to March 19, where it was more than usually common the fall of 1875 (Reid). In Texas it has been reported south to Corpus Christi (Saunders) and to Fort Brown (Merrill). A few pass south of the United States to Progreso, Yucatan, March 22 (Stone); the mouth of the Colorado River (Rhoads); Cerros Island, Lower California, January, 1885 (Bryant), and a few at the Tres Marias, May 22, 1897 (Nelson). The European birds winter south to the Mediterranean and Caspian Seas.

Spring migration of the herring gull.

Place.	Number of years' records.	Average date of spring arrival.	Earliest date of spring arrival.	Place.	Number of years' records.	Average date of spring arrival.	Earliest date of spring arrival.
Renovo, Pa.	7	Feb. 17	Feb. 5, 1911	Athabaska River, Alberta, latitude 55°			May 7, 1901
Montreal, Canada	4	Apr. 22	Apr. 13, 1892	Fort Resolution, Mackenzie			May 17, 1860
Quebec City, Canada	6	Apr. 17	Apr. 10, 1901	Fort Simpson, Mackenzie	3	May 22	May 14, 1868
Godbout, Quebec			Apr. 3, 1888	Pelly Lake, Yukon			May 16, 1893
Pictou, Nova Scotia			Apr. 8, 1895	Fort Enterprise, Mackenzie			May 21, 1910
North River, Prince Edward Island	3	Apr. 2	Apr. 1, 1887	Igloolik, Franklin			Apr. 19, 1823
Ottawa, Ontario	22	Apr. 4	Mar. 13, 1894	Winter Island, Franklin			May 3, 1822
Madison, Wis.	8	Mar. 19	Mar. 2, 1904	Bay of Mercy, Franklin			May 31, 1852
Heron Lake, Minn.	6	Mar. 27	Mar. 20, 1889	Prince of Wales Strait, Franklin			June 7, 1851
Harrisburg, N. Dak.	2	Apr. 7	Apr. 3, 1904				
Aweme, Manitoba	16	Apr. 11	Apr. 2, 1906				
Indian Head, Saskatchewan (near)	9	Apr. 27	Apr. 19, 1910				
Osler, Saskatchewan			May 1, 1893				
Edmonton, Alberta (near)	3	May 2	May 1, 1911				

Place.	Number of years' records.	Average date of the last one seen.	Latest date of the last one seen.	Place.	Number of years' records.	Average date of the last one seen.	Latest date of the last one seen.
Tortugas, Fla.			Apr. 27, 1914	Jersey City, N. J. (near)	3	May 10	May 14, 1910
Clearwater Harbor, Fla.			May 21, 1886	Central New York	15	May 15	June 2, 1906
Cumberland, Ga.			Apr. 16, 1902	Providence, R. I. (near)	5	May 13	June 12, 1900
Charleston, S. C.			May 2, 1910	Woods Hole, Mass.	4	June 11	July 4, 1904
Pea Island, N. C.			May 3, 1902	New Orleans, La.			Mar. 25, 1894
Waverly, W. Va.	3	Mar. 22	Mar. 25, 1906	Bay St. Louis, Miss.			Mar. 26, 1902
Washington, D. C.	4	Apr. 27	May 10, 1887	Brazos, Tex.			Mar. 24, 1853
Baltimore, Md.			May 28, 1897	St. Louis, Mo.	2	Apr. 15	May 28, 1887
Beaver, Pa.	3	Apr. 10	Apr. 16, 1890	Chicago, Ill.	6	Apr. 23	June 15, 1909
Erie, Pa.			May 16, 1875				
Renovo, Pa.	6	Apr. 20	May 16, 1907				

Fall migration of the herring gull.

Place.	Number of years' records.	Average date of fall arrival.	Earliest date of fall arrival.
Woods Hole, Mass.	5	Aug. 21	Aug. 8, 1887
Central New York	7	Aug. 20	Aug. 13, 1908
Jersey City, N. J.	2	Sept. 21	Sept. 20, 1905
Erie, Pa.			Aug. 22, 1900
Charleston, S. C.			Nov. 5, 1911

Place.	Number of years' records.	Average date of fall arrival.	Earliest date of all arrival.
Savannah, Ga.	3	Nov. 3	Oct. 28, 1910
Tortugas, Fla.			Dec. 12, 1887
Keokuk, Iowa	6	Oct. 8	Sept. 1, 1900
Chicago, Ill.			Aug. 8, 1906
Hickman, Ky.			Oct. 14, 1886

Place.	Number of years' records.	Average date of the last one seen.	Latest date of the last one seen.
Winter Island, Franklin			Sept. 15, 1821
Wellington Channel			Sept. 8, 1852
King Oscar Land			Oct. 30, 1899
Montreal, Quebec	7	Nov. 5	Dec. 11, 1891
Pictou, Nova Scotia			Dec. 18, 1894
North River, Prince Edward Island			Dec. 25, 1889
Ottawa, Ontario	12	Nov. 7	Nov. 21, 1892

Place.	Number of years' records.	Average date of the last one seen.	Latest date of the last one seen.
Pelly River, Yukon			Oct. 7, 1904
Fort Wrigley, Mackenzie (near)			Oct. 13, 1903
Fort Resolution, Mackenzie	2	Sept. 22	Sept. 25, 1907
Killarney, Manitoba	5	Oct. 18	Oct. 30, 1910
Aweme, Manitoba			Nov. 7, 1899

Nonbreeding herring gulls are not rare during summer at many places south of the breeding range: Coosaw River, S. C., July 20, 1892; Erie, Pa., still common in early June, 1912; near New Haven, Conn., June 29, 1877; and common all summer on Pelee Island, in Lake Erie. The number of these summer nonbreeding birds on Long Island has largely increased within the past few years (Braislin).

Eggs have been taken at Midriff Lake, N. Y., May 15, 1894 (specimens in U. S. National Museum); Kentville, Nova Scotia, May 27 to July 5 (Bishop); Rowleys Bay, Wis., May 27, 1878 (specimens in U. S. National Museum); Great Duck Island, Me., May 27, 1900, and May 15, 1902 (Dutcher); Sturgeon Island, Lake Winnipeg, June 1, 1889 (Macoun); Great Whale River, Quebec, June 12, 1899 (Eifrig); Fort Resolution, Mackenzie, June 25, 1860 (Kennicott); Fort Anderson, Mackenzie, June 27, 1863 (MacFarlane), and Bellot Strait, June 25, 1859 (M'Clintock).

Probably the largest breeding colony of herring gulls in the United States is on Great Duck Island, Me., where in 1902 it was estimated that 3,400 pairs were nesting (Dutcher). The nesting season is extended, for eggs were found on an island in Penobscot Bay as late as August 19, 1896 (Knight).

One of the most interesting records of bird migration ever secured is that of a herring gull which wintered for many years at the Brenton Reef Lightship, near Newport, R. I. This gull—called by the lightkeeper "Dick"—came each day during winter to be fed. It was first noted and fed in the fall of 1872, but, of course, there was no way of knowing how old the bird was at that time. It continued to visit the lightship and spend the winter in the immediate vicinity for 24 consecutive years, outliving all the lightship attendants who first fed it. During the last years it arrived October 5, 1890; October 12, 1891; September 28, 1892; October 7, 1893; October 2, 1894; and October 2, 1895. It was last seen in spring April 6, 1892; April 7, 1893; April 5, 1894; April 6, 1895, and April 7, 1896—a remarkably uniform date of departure.

VEGA GULL. *Larus vegæ* Palmén.

Knowledge concerning the distribution and migration of the Vega gull is very limited. It was originally described from specimens taken at Pidlin, on the northern coast of Siberia, where the ship *Vega* had wintered, and it has since become known along that coast from the Taimyr Peninsula east to Bering Strait, on the Liakoff Islands, and at Plover Bay, where it is common, and also along the coasts of Kamchatka and the Sea of Okhotsk. A specimen now in the United States National Museum was taken by Nelson on Diomede Island in Bering Strait, in July, 1881. In migration and winter this gull has been taken on the coasts of Japan and China, south to Formosa and the Ogasawara (Bonin) Islands.

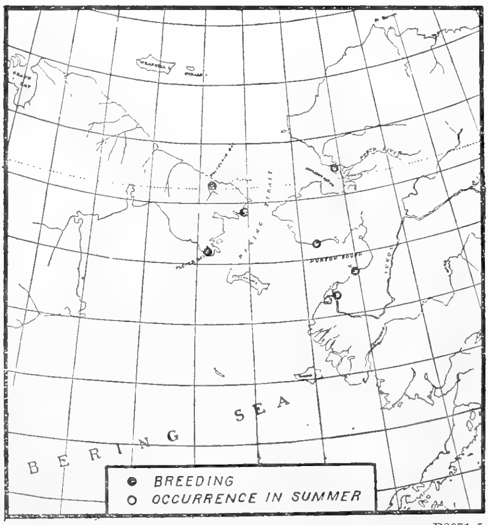

Fig. 20.—Vega gull (*Larus vegæ*). B2071-5

Information concerning the occurrence of the Vega gull on the eastern side of Bering Strait is less satisfactory. Under the name of *Larus borealis*, Baird notes a specimen from Norton Sound, and the catalogue of the United States National Museum records that it was taken by Bischoff at St. Michael in May; Nelson records a specimen of *Larus cachinnans* that was brought to him at St. Michael, October 16, 1880, and thinks that he saw the same species on several other occasions, and that it occurs on the Alaska coast from Kotzebue Sound to the mouth of the Yukon. Both these names, *borealis* and *cachinnans*, refer to *Larus vegæ*, whose occurrence on the Alaskan coast was made certain in 1910 by the capture of four specimens at Nome, September 2–14, (Thayer). One of these was identified at the Biological Survey. Whether or not the species breeds to the eastward of Bering Strait remains for future determination.

Eggs were taken in the Kolyma delta, Siberia, June 26, 1912, and at Cape Bolshaja, Baranof, July 12, 1912. Even as late as September 10, 1911, young fully fledged but still being fed by their parents were seen at Cape Kibera Island (Thayer and Bangs).

CALIFORNIA GULL. *Larus californicus* LAWRENCE.

Range.—Western North America from the lower Anderson River, Mackenzie, to Oaxaca, Mexico.

Breeding range.—The California gull breeds throughout a great extent of latitude, but in this wide range the nest has been found at only a few places: Fort Anderson and the lower Anderson River, Mackenzie (MacFarlane), though probably rare, if anything more than casual, so far north; Great Slave Lake from Fort Resolution to Fort Rae (eggs in U. S. National Museum); Big Stick Lake and Crane Lake, Saskatchewan (Bent); Stump Lake, N. Dak. (Eastgate); Devils Lake, N. Dak., common (Job and Bishop); Great Salt Lake (Ridgway); Utah Lake (Goodwin); Malheur Lake and Lower Klamath Lake, Oreg. (Finley); Pyramid Lake and Soda Lake, Nev. (Ridgway); Clear Lake, Cal. (Finley); Eagle Lake, Cal. (Townsend), and Mono Lake, Cal. (Brewster).

Winter range.—The principal winter home of the California gull is along the coast of the State from which it derives its name and north to Portland, Oreg. (Anthony). A few remain in winter on Great Salt Lake (Goodwin), and the species ranges south at this season to the coast of Lower California, being common even as far south as La Paz (Bryant). Thence it has occurred at Rio de Coahuayana, Colima (Brewster); Manzanillo, Colima (Nelson); Alvarado, Vera Cruz (Ferrari-Perez); and San Mateo, Oaxaca, February, 1869 (Sumichrast). It is also fairly common in winter at the head of the Gulf of California (Rhoads), and inland to the Salton Sea, Cal. (Grinnell) and to Owens Lake, Cal. (Fisher).

Migration range.—Outside the usual breeding and winter ranges the California gull has been taken at Fort Simpson, Mackenzie (specimen in U. S. National Museum); Many Island Lake, Alberta, June 18 to July 13, 1906 (Bishop); Reno County, Kans., October 20, 1880 (Goss); Galveston, Tex. (Singley); Laredo, Tex., October 16, 1866 (specimen in U. S. National Museum); Denver, Colo., October 26, 1878 (Carter); Middle Park, Colo., at 7,000 feet altitude, April 28, 1884 (Carter); Coventry, Colo., one in 1905 (Warren); Loveland, Colo., May 7, 1890 (Osburn); Larimer County, Colo., April 18, 1894 (Breninger); Hawaii, once (Bryan); British Columbia, on the coast north to Cormorant Island, May 24, 1911 (Wetmore); and at Hot Springs, Atlin, British Columbia, July 16, 1914 (Kermode).

Spring migration.—The first of these gulls was seen at Okanogan Lake, British Columbia, April 11, 1907 (Brooks); Devils Lake, N. Dak., April 24, 1903 (Bowman); Harrisburg, N. Dak., April 25, 1904 (Eastgate); and the last at Catalina Island, Cal., May 12, 1897 (Grinnell); Monterey, Cal., May 19, 1897 (Loomis); and San Jose del Cabo, Lower California, May 17, 1882 (Belding).

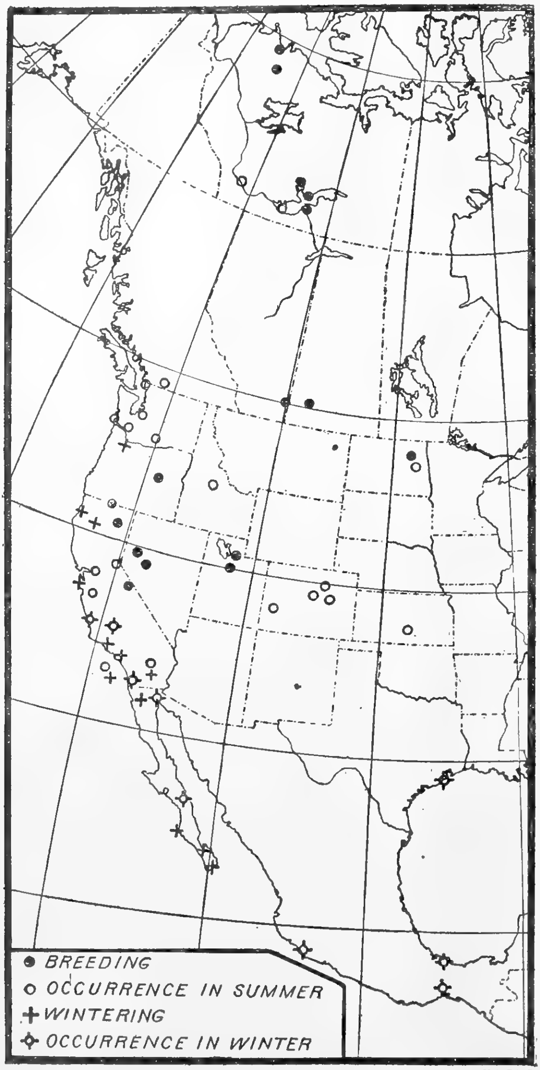

FIG. 21.—California gull (*Larus californicus*).

Eggs have been taken at Pyramid Lake, Nev., May 16, 1868, May 15, 1875, and June 4, 1891 (specimens in U. S. National Museum); Carrington Island in Great Salt Lake, June 17, 1869 (Ridgway); Fort Resolution, Mackenzie, June 26, 1860 (specimens in U. S. National Museum); young just hatched, at Big Stick Lake, Saskatchewan, June 14, 1906 (Bent); and young, a few days old, on Loon Island, Great Slave Lake, July 13, 1901 (Preble).

Fall migration.—A single California gull, unusually early, appeared at Monterey, Cal., August 1, 1894; no more were seen until August 21, and by the first of September the species was fairly common. In 1896 the first was not seen until September 28, the next October 9, and it was common from this latter date (Loomis). At Berkeley, Cal., the first was seen October 9, 1888 (Palmer); near San Pedro, Cal., September 13, 1902 (Daggett); Magdalena Island, Lower California, November 24, 1905 (Nelson and Goldman); Puget Sound, Wash., August 3 and 12 (specimens in U. S. National Museum); and Chilliwack, British Columbia, August 26, 1889 (Brooks). The last was seen at Hay River, Mackenzie, November 5, 1908 (Jones).

RING-BILLED GULL. *Larus delawarensis* Ord.

Range.—North America from British Columbia, southern Mackenzie, and central Quebec south to Florida and southern Mexico.

Breeding range.—The ring-billed gull occupies in summer a rather narrow belt stretching across North America with its northern side beginning at Hamilton Inlet, Quebec (Macoun), and extending to Fort George, on James Bay (eggs in U. S. National Museum); a little north of Fort Churchill, Keewatin (Preble); and Great Slave Lake,

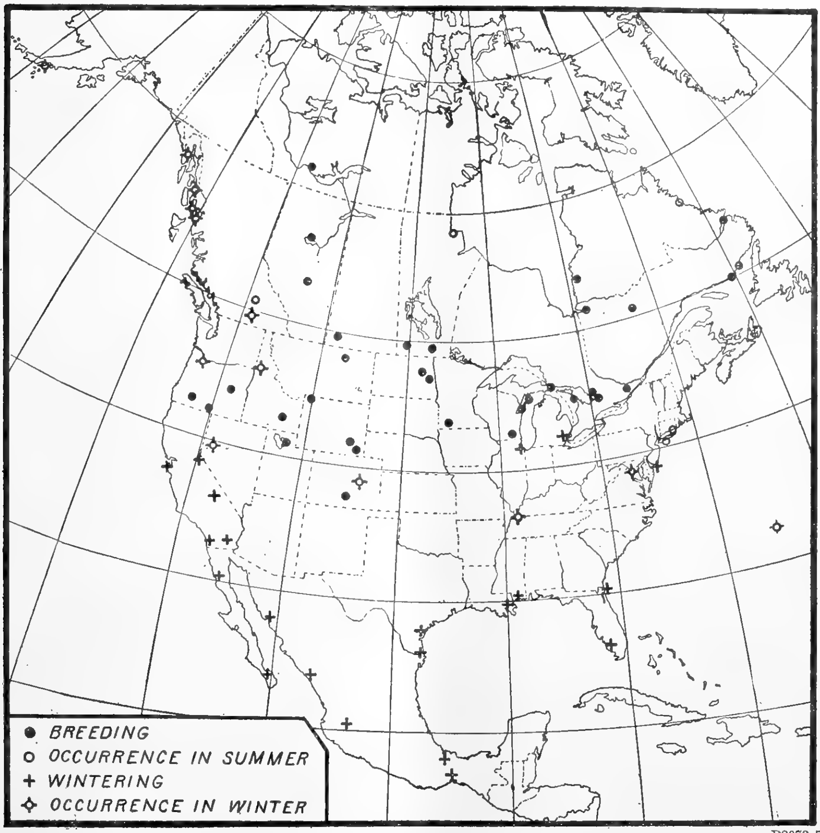

Fig. 22.—Ring-billed gull (*Larus delawarensis*). B2073-5

Mackenzie (Kennicott). The distribution on the Pacific slope is not so far northward. The species is known to breed on Malheur Lake and Lower Klamath Lake, in southern Oregon (Finley), and at Buffalo Lake, near Red Deer, Alberta (Dippie). It was common at Shuswap Lake, British Columbia, in June, 1889 (Macoun). It breeds south to Cape Whittle, in the Gulf of St. Lawrence (Frazar); the islands in Georgian Bay (Fleming); formerly on the islands in Green Bay, Wis., and in 1860 at Lake Koshkonong (Kumlien and Hollister); in 1892 on Gull Island, near Vans Harbor, Mich. (Van Winkle); Heron

Lake, Minn. (Roberts); Devils Lake, N. Dak. (Job); San Luis Lakes, Colo. (Cooke); Great Salt Lake, Utah (Saunders); and Minidoka, Idaho (Dille).

Winter range.—The principal winter home of this gull along the Atlantic coast is from North Carolina to Florida, but a few remain in the Chesapeake Bay and rarely on the New Jersey coast—Cape May, January, 1892 (Stone)—while it is a straggler in winter still farther north. It can usually be found at Detroit, Mich., and on Lake Michigan during winter, and at Chicago, Ill., it was common the whole winter of 1894–95 (Parker). It is common on the Gulf coast in winter, south to Fort Myer, Fla. (Scott), and to Brownsville, Tex. (Merrill), while in the interior it has been known to occur at Washington, D. C., January 23, 1887 (Fisher); Hickman, Ky., January 1, 1887 (Pindar); Barr Lake, Colo., occasional in winter (Rockwell); near Colorado Springs, Colo., about January 1, 1890 (Aiken and Warren); Fort Sherman, Idaho, once in January (Merrill); Lewistown, Mont., one, December 31, 1898, killed by eating of the carcass of a sheep that had been poisoned as bait for coyotes (Silloway); and Pyramid Lake, Nev., December 21, 1867 (Ridgway). On the Pacific coast it winters from San Francisco Bay, Cal., to San Diego, and, in the interior, on Owens Lake, Salton Sea, and Lake Tahoe (Grinnell); also south to San Quintin, Lower California, December 27, 1905, to January 21, 1906 (Thayer); La Paz, Lower California, February 15, 1882 (Brewster); Mazatlan (Lawrence); Guaymas, December; Presidio, January and February; Santa Ana, near Guadalajara, November (Saunders); and Tehuantepec, February 21, 1869, and in March (Sumichrast). It occurs casually in winter north to Portland, Oreg. (Anthony), Bellingham Bay, Wash. (Edson), and to the Lower Fraser Valley and Lake Okanogan (Brooks). A straggler was taken in Bermuda, January 1, 1849 (Reid).

Migration range.—A specimen of the ring-billed gull was taken September 6, 1900, at Port Manvers, on the Labrador coast (Bigelow). It is reported as occurring in Newfoundland (Reeks); at Ingonish, Cape Breton Island (Townsend); and was seen during the fall of 1911 in Alaska as follows: Kings Cove, the middle of August; Icy Strait, August 30; Wrangell Narrows, August 31; and Ketchikan, September 1 (Wetmore). One was taken May 24, 1911, near Campbell Island, British Columbia (Beck), and August 6–18, 1897, the species was common in flocks along the British Columbia coast near Port Simpson (Preble). The first record for Hawaii is that of an individual taken February 1, 1901 (Bryan).

Spring migration.—The first spring migrants of this species usually appear at Washington, D. C., in February—February 5, 1900, and February 16, 1913; Canandaigua, N. Y., February 1, 1906 (Antes); Rockaway Beach, N. Y., February 13, 1910 (Griscom and Dow);

Saybrook, Conn., March 8, 1887 (Clark); and had reached the coast of Newfoundland by April 19, 1883 (Merriam).

In the interior the first were reported at Grand Rapids, Mich., March 28, 1891 (White); St. Louis, Mo., March 7, 1909 (Betts); Keokuk, Iowa, March 8, 1903 (Currier); Storm Lake, Iowa, March 15, 1888 (Bond); Canton, Ill., March 9, 1897 (Cobleigh); Madison, Wis., average March 19, earliest March 12, 1911; Lanesboro, Minn., March 23, 1893 (Hvoslef); Heron Lake, Minn., average April 1, earliest March 22, 1894 (Miller); White Earth, Minn., April 3, 1882 (Cooke); Lincoln, Nebr., average April 3, earliest March 28, 1899 (Wolcott); near Valentine, Nebr., average April 1, earliest March 12, 1893 (Bates); Sioux Falls, S. Dak., March 19, 1911 (Larson); Vermilion, S. Dak., March 31, 1884 (Agersborg); near Devils Lake, N. Dak., average April 16, earliest April 11, 1895; southern Manitoba, average April 25, earliest April 21, 1905; Indian Head, Saskatchewan, April 11, 1908 (Lang); mouth of Pelican River, Mackenzie, May 9, 1901 (Preble); Pecks Lake, Ariz., April 13, 1886 (Mearns); Fort Verde, Ariz., April 17, 1888 (Mearns); Loveland, Colo., average March 14, earliest March 9, 1890 (Smith); San Luis Lakes, Colo., April 4, 1887 (Woodbury); Coventry, Colo., April 13, 1906 (Smith); Great Falls, Mont., average April 6, earliest April 5, 1890 (Williams); and Stony Plain, Alberta, April 24, 1911 (Stansell).

The last in spring were noted at Big Gasparilla Pass, Fla., May 22, 1886 (Scott); Pea Island, N. C., May 10, 1906 (Bishop); Washington, D. C., April 28, 1887 (Fisher); Erie, Pa., April 26, 1902 (Todd); Loyalhanna Creek, Pa., May 7, 1881 (Townsend); Atlantic City, N. J., June 20, 1900 (Stone); Geneva, N. Y., May 24, 1888 (Miller); New Orleans, La., April 28, 1894 (Beyer); Bay St. Louis, Miss., March 29, 1902 (Allison); Kansas City, Mo., May 3, 1902 (Bryant); Chicago, Ill., June 21, 1907 (Armstrong); Sioux City, Iowa, May 8, 1904 (Rich); Spirit Lake, Iowa, June 14, 1890 (Berry); Madison, Wis., May 17, 1905 (Blackwelder); Corpus Christi, Tex., April 12, 1889 (Sennett); Emporia, Kans., May 6, 1884 (Kellogg); Hyperion, Cal., May 24, 1910 (Grinnell); and Quinn River, Nev., June 1, 1909 (Taylor).

Nonbreeding individuals remain all summer along the coast of Long Island (Braislin), on Lake Ontario near Kingston (Clarke), on Lake Michigan, and on the small interior lakes of Wisconsin (Kumlien and Hollister), and Barr Lake, Colo. (Rockwell).

Eggs have been taken from June 20, 1884, in southeastern Labrador to August 3, 1860, at Rupert House, Quebec (specimens in U. S. National Museum). Eggs were obtained May 23, 1898, at Devils Lake, N. Dak. (Job), and June 13, 1893, at Stump Lake, N. Dak. (Knight). Audubon found many eggs, but none of them hatched, June 18, 1833, at Little Mecattina, on the north coast of the Gulf of

St. Lawrence, latitude 50°. In the same latitude at Crane Lake, Saskatchewan, young were already out of the shell, June 9, 1894 (Spreadborough). Young not yet able to fly were noted near Strater, Mont., July 18, 1910 (Anthony).

Fall migration.—The first fall migrant of the species was noted at Woods Hole, Mass., September 17, 1891 (Edwards); Wildwood, N. J., September 7, 1895 (Stone); Pea Island, N. C., July 23 and August 20, 1904 (Bishop); Charleston, S. C., September 26, 1909 (McDermid); Savannah, Ga., September 30, 1909, and common by October 6 (Perry); and Fernandina, Fla., July 13, 1906, next seen August 3, and common September 16 (Worthington). It is evident that these July records refer either to nonbreeding birds that have spent the summer south of the regular summer home or to birds that having lost their eggs or young have started early on their southward journey.

The first appeared at Delavan, Wis., August 18, 1892, and the next, September 1 (Hollister); Toronto, Ontario, August 20, 1890 (Fleming); Point Pelee, Ontario, August 24, 1907 (Taverner); Lake Forest, Ill., August 8, 1906 (Ferry); Bay St. Louis, Miss., October 10, 1901, common by October 14 (Allison); Lincoln, Nebr., August 14, 1900 (Wolcott); Denver, Colo., August 21, 1910 (Williams); Okanogan Lake, British Columbia, July 28, 1907, and August 8, 1911 (Brooks); Chilliwack, British Columbia, August 13, 1888, and August 15, 1889 (Brooks); Alamitos Bay, Los Angeles County, Cal., September 17, 1907 (Grinnell).

The last one seen in 1901 on Anticosti Island was on September 18 (Schmitt); Woods Hole, Mass., November 17, 1889 (Edwards); near Newport, R. I., December 1, 1900 (Mearns); Erie, Pa., October 17, 1900 (Worthington); Harrisburg, N. Dak., October 17, 1901 (Eastgate); Denver, Colo., November 12, 1908 (Rockwell); Provo, Utah, November 30, 1872 (Henshaw); and Valentine, Nebr., November 15, 1894 (Bates).

SHORT-BILLED GULL. *Larus brachyrhynchus* Richardson.

Range.—Western North America from northwestern Mackenzie to southern California.

Breeding range.—The short-billed gull was originally described from a specimen taken at Fort Franklin, Great Bear Lake, Mackenzie, May 23, 1826 (Richardson), from nearly the northern limit of its range, the species breeding only a little farther north, to Fort Anderson (MacFarlane). Thence it ranges in the breeding season west to Fort Yukon (Dall) and the mouth of the Kowak River (Grinnell). The principal summer home of the species is in Alaska, where it breeds west to Cape Lisburne (eggs in U. S. National Museum); Nelson Island (Thayer); and Nushagak (eggs in U. S. National Museum); and south to Morshovoi Bay (Littlejohn); Kodiak Island (U. S. National Museum);

Homer (Chapman); Montague Island (Grinnell); Yakutat (Blackwelder); and Glacier Bay (Fisher). Inland it breeds south to Lake Marsh (Bishop); Hot Springs and Pike River, Atlin, British Columbia (Kermode); and is a common breeder in the Mackenzie Valley south to the lower Slave River (Preble) and to the Charlot River on Lake Athabaska (Harper).

Winter range—This gull winters on the Pacific coast from Vancouver Island (Kermode) to extreme southern California at San Diego

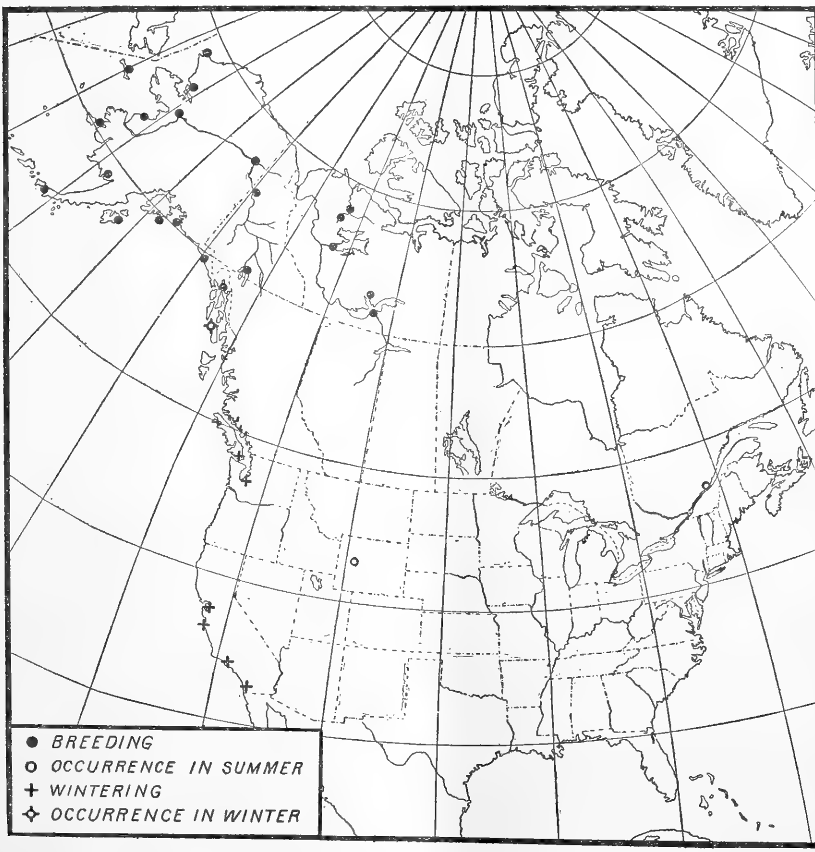

FIG. 23.—Short-billed gull (*Larus brachyrhynchus*).

(Henshaw), and occasionally as far north as Sitka, Alaska, where it was taken in December 1865, and January, 1866 (specimens in U. S. National Museum).

There are three records of extensive wanderings: One was taken near Quebec City, Canada (Dionne); one on the Kuril Islands in February (Saunders), and a specimen now in the collection of the Biological Survey was taken August 28, 1893, on Lake Fork, in the Wind River Mountains, Wyo., at 10,000 feet altitude (Bailey).

Spring migration.—One of these gulls was noted in Queen Charlotte Sound, British Columbia, April 6, 1909 (Swarth); Windfall Harbor, Admiralty Island, Alaska, April 24, 1907 (Grinnell); St. Michael, Alaska, May 11, 1866 (specimen in U. S. National Museum); Mount McKinley, Alaska, near base, May 10, 1908 (Sheldon); Fort Simpson, Mackenzie, May 8, 1904 (Preble); and the lower Kowak River, Alaska, May 15, 1899 (Grinnell).

Eggs were taken on the Lockhart River, Mackenzie, as early as May 28, 1862 (MacFarlane); Fort Resolution, Mackenzie, June 7, 1860 (Kennicott); Fort Rae, Mackenzie, June 6, 1862 (specimen in U. S. National Museum); mouth of Porcupine River, Yukon, June 9, 1865 (U. S. National Museum); St. Michael, Alaska, June 6, 1878 (U. S. National Museum); Cape Lisburne, Alaska, June 10, 1885 (U. S. National Museum); Montague Island, Alaska, July 5, 1908 (Grinnell); and downy young on Hawkins Island, Alaska, June 23, 1908 (Grinnell), and at Lake Marsh, Yukon, July 1, 1899 (Bishop). The species was common all the summer of 1907 at various localities in the Sitka district, but apparently none were breeding (Grinnell).

Fall migration.—A specimen taken July 30, 1856, in Puget Sound (U. S. National Museum) probably represents an early fall migration of a nonbreeding bird, as also those seen July 18, 1909, at Bradfield Canal, British Columbia (Swarth). The first was noted at Chilliwack, British Columbia, August 26, 1889 (Brooks); Scio, Oreg., September 21, 1900 (Prill); Berkeley, Cal., October 9, 1886 (Keeler); Monterey, Cal., October 29, 1896 (Loomis); Ventura, Cal., November 26, 1884 (Henshaw); and San Diego, Cal., December 11, 1884 (Henshaw).

The species departed from the lower Kowak River, Alaska, the last week in August, 1898 (Grinnell); the last were at Cape Nome, Alaska, August 28, 1910 (Thayer); Icy Cape, Alaska, July 30 (Seale); Collinson Point, near Camden Bay, Alaska, September 8, 1914 (Anderson); St. Michael, Alaska, September 23, 1899 (Bishop); near Lake Hardisty, Mackenzie, August 25, 1903 (Preble); and Petersburg, near Sitka, Alaska, October 7, 1913 (Willett).

An interesting question arises in connection with the migration route of those individuals that breed in the Mackenzie Valley. Migration dates show that the birds do not enter Mackenzie by way of the Yukon Valley, for the arrival dates are as early at Fort Simpson, Mackenzie, as at the mouth of the Yukon. Future investigations will undoubtedly show that these Mackenzie Valley birds make a direct flight from the coast of southern Alaska to Great Slave Lake, though this requires that they cross the divide of the Rocky Mountains—here about 2,500 feet high—in early May, when even the lowest passes are still deep in snow.

[**MEW GULL.** *Larus canus* LINNÆUS.

The mew gull is a species of the Eastern Hemisphere, having there a wide range from northern Europe and Asia to the Mediterranean, the Nile, and the Persian Gulf. On the Pacific coast it occurs from the northern coast of the Sea of Okhotsk, Kamchatka, and Bering Island, to Japan and China.

The only sure record for North America is that of a specimen taken by Dr. Coues at Henley Harbor, Labrador, August 21, 1860. This specimen found its way to the British Museum.

The mew gull has been erroneously recorded several times on the coast of California. One recorded November 30, 1905, at Pacific Beach, was a young ring-billed gull, and one reported April 14, 1907, from Alamitos Bay proved to be the Pacific kittiwake. Early records of Loomis and late records of Beck, from Monterey Bay, are referable to the short-billed gull.]

HEERMANN'S GULL. *Larus heermanni* CASSIN.

Range.—Pacific coast from British Columbia to Mexico.

Heermann's gull is the only member of the group that regularly migrates in summer to the north of its breeding grounds and is common in the United States at that season, though not as yet known to breed north of Mexico. Up to date only a few nesting places are known. In April, 1875, Dr. Streets found an immense colony preparing to breed on Isla Raza, on the west side of the Gulf of California near latitude 29°. Though eggs had not yet been laid, the birds were mating, and the presence of many thousands of tons of guano bore witness to the fact that the island had been used as a breeding place for untold generations.

The eggs of Heermann's gull have been among the desiderata of collectors for many years, and it is noteworthy that they should at last have been found in the same month at widely separated localities by two expeditions sent out principally for this purpose. W. W. Brown, jr., collecting for J. E. Thayer, found a colony, March 28, 1909, on Idlefonso Island, near the west coast of the Gulf of California, latitude 26° 30′. The first eggs from a colony whose nests were estimated as at least 2,500 were not obtained until April 2. Nine days later eggs were found by Osburn and Lamb on Las Marietas Islands, off the coast of Jalisco, latitude 20° 30′. The eggs at the more southern colony, which contained less than a hundred pairs, had been laid so much earlier that some hatched April 14.

The original discoverer of this species, Dr. A. L. Heermann, said that it bred on Los Coronados Islands, Lower California, near San Diego, but this statement was probably not based on the finding of the eggs, but on the presence of the bird on the near-by coast during the breeding season. Later observers have failed to find the species nesting on these islands, or, indeed, anywhere along the whole western coast of Lower California, though it has been reported breeding at Magdalena Bay (Bryant), on the Tres Marias (Bailey), and at Mazatlan (Lawrence).

The species is present the whole year on the coast of Lower California and western Mexico from the United States boundary to Tepic, a distance of over a thousand miles, and it is not probable that all these untold thousands of birds gather for nesting purposes on the few acres of the two islands where their eggs have been obtained.

As soon as the young birds are strong of wing both old and young begin to work their way northward. On the southern coast of California, where only a few birds are present after the middle of March, the numbers begin to increase the last week in May and early in June (Willett). The first northward migrant reached Eureka, Cal., June 1, 1889 (Palmer), and William Head, Vancouver Island, British Columbia, June 28, 1904 (Kermode). The species is an abundant summer migrant along the whole coast and has been taken north to the northern end of Vancouver Island (Saunders).

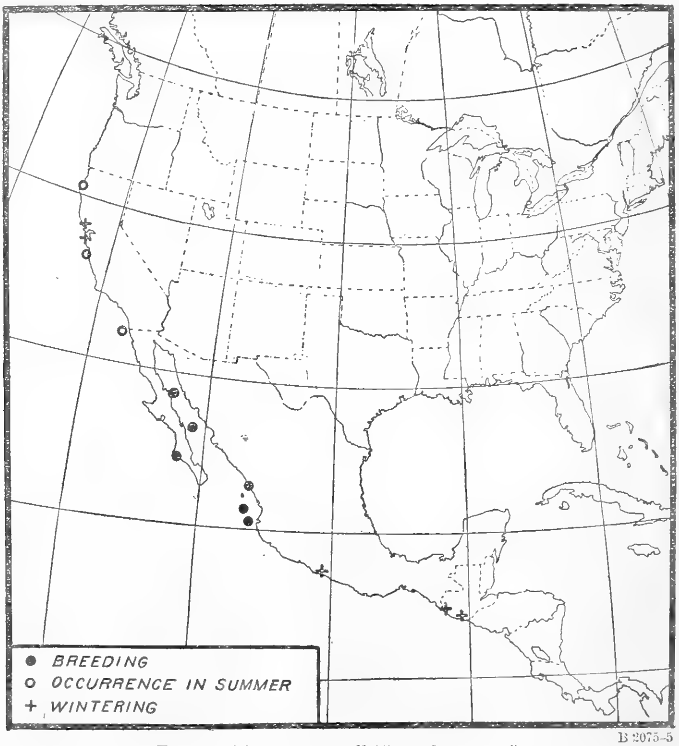

FIG. 24.—Heermann's gull (*Larus heermanni*).

Its stay in this northern part of the range is not prolonged. In 1894, by the end of July flocks were beginning to pass southward at Monterey Bay, Cal. (Loomis). Though common during July and August at the southern end of Vancouver Island (Kermode), by

September so many had started south that during this month at Yaquina Bay, Oreg. (Bretherton), it outnumbered all other gulls. It is an abundant southward migrant at Monterey, Cal., from August through October, but its numbers begin to decrease in early November (Loomis). The last leave Fort Rupert, at the north end of Vancouver Island, British Columbia, in October (Saunders), and only a few were still present in November, 1889, as far north as Ilwaco, Wash. (Chapman). A specimen was taken at Bodega Bay, Cal., as late as December, 1854 (Lawrence), and a few remain all winter as far north as San Francisco Bay (Henshaw), and casually—January, 1896—even at Esquimault, British Columbia (Macoun). It is less rare at Monterey Bay during the winter (Loomis) and common at that season along the coast of southern California (Willett). It ranges south in winter to Chiapam and San Jose, Guatemala, where specimens were taken in January, 1863 (Salvin). A few were noted in Acapulco Bay, Guerrero, April, 1903 (Nelson and Goldman).

LAUGHING GULL. *Larus atricilla* Linnæus.

Range.—Atlantic coast from Maine to British Guiana, the Gulf of Mexico, and the Pacific coast of western Mexico and Guatemala.

Breeding range.—The laughing gull is preeminently a breeding bird of eastern Caribbean Sea. It is a common breeder on the islands of Aruba, Bonaire, Curacao (Hartert), and Margarita (Clark), off the coast of Venezuela, and on the southern islands of the Lesser Antilles—Grenada, Carriacou, Barbuda, Grenadines, and Soufrière. It is recorded from the others of the Lesser Antilles and from Porto Rico and Haiti, but though it undoubtedly breeds at many places throughout this region there is apparently no specific record of the finding of eggs. The bird reappears as a breeder in Jamaica (Field); Cuba (Gundlach); on the coast of Campeche, at Arcas Keys (Nelson); probably at Saddle Cay, British Honduras (Salvin); and the northern Bahamas—Andros, New Providence, Cat, Watling, and probably many other islands, as the species ranges throughout the Bahamas.

Along the United States coast from Florida to Maine the laughing gull was formerly an abundant breeder and 50 to 60 years ago nested in great numbers at many places. A large part of these colonies have been extirpated by the plume hunter, but some birds escaped the slaughter, and during the last few years, under the careful protection of the National Government and of the National Association of Audubon Societies, these remaining colonies have increased in size and the birds are returning to others of their former homes.

On the western and southern coasts of Florida these gulls breed near Passage Key (Pillsbury) and on a key near Cape Sable (Bent and Job). Many of the birds were seen during June, 1904, near Key West, indicating a breeding colony not far distant. The next colony to the north is on Royal Shoal, Pamlico Sound, N. C., where about 250 birds were nesting in 1909 (Philipp). The coast of northeastern Virginia is the home of the largest colonies in the United States. Here the birds breed commonly on most of the islands from Cobbs Island (Harper) to Chincoteague (Knight). In 1902 about 2,000 birds were nesting on the former. The birds still breed at Brigantine and on Gull Island, N. J., a few in each place (Stone), and some 500 birds near Stone Harbor (Carter). It is probable that a few pairs also still

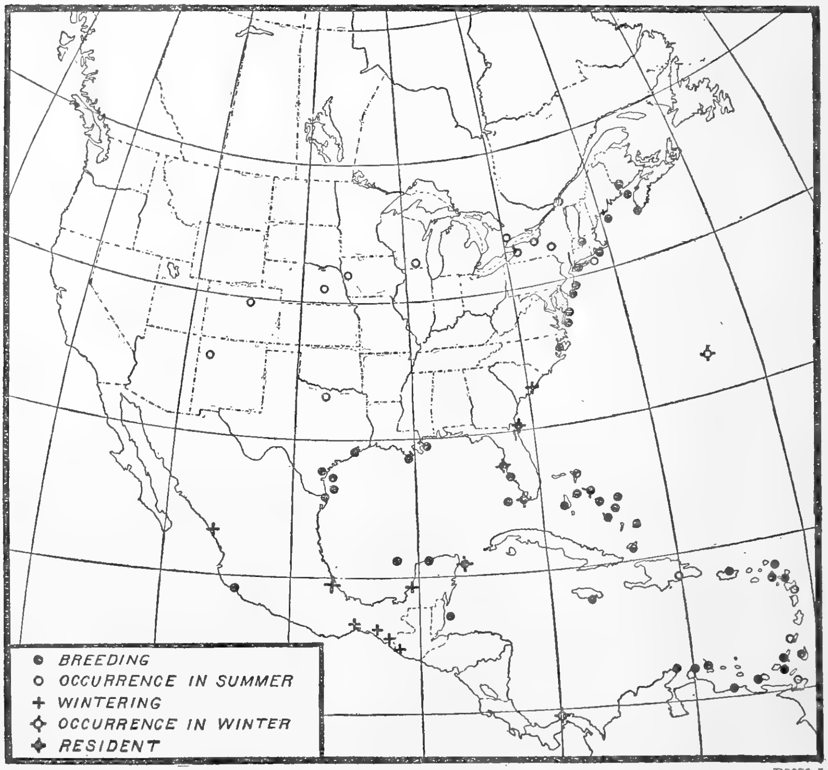

FIG. 25.—Laughing gull (*Larus atricilla*).

breed around Great South Bay, Long Island (Eaton). Sixty years ago on the islands off the Massachusetts coast the laughing gull was a common breeder; now it is restricted to Muskeget Island, but the colony there during the past few years has increased until in 1908 it was estimated to contain a thousand birds (Forbush).

Only one colony of the laughing gull remains in the States north of Massachusetts, and that, near Penobscot Bay, on the coast of Maine, is reduced to scarcely a dozen individuals. Previous to 1870, the species nested at several places along the coast east to the vicinity of Grand Manan, and in the summer of 1856 Dr. Bryant collected two pairs nesting on Green Island, near Yarmouth, Nova Scotia.

The species is a common breeder on the islands off the coast of Louisiana—East Timbalier, Tern, Breton, and Battledore (Job)—and it still breeds on Bird and Padre Islands and Matagorda Peninsula, on the coast of Texas (Strecker), where 30 years ago it nested at many places from Galveston to Brownsville.

Winter range.—On the Atlantic coast, birds of this species retire in winter to South Carolina and are abundant at Charleston all through the cold season (Wayne). Thence they range throughout the West Indies, and a very few wander south of the breeding range to Georgetown, British Guiana (Loat); Surinam (Saunders); and to Cajutuba, Brazil, February 20, 1835 (Pelzeln). The laughing gull is a common winter bird on the United States coast of the Gulf of Mexico, and less common on the Mexican coast. It even crosses Mexico to the Pacific, where it has been noted on the coast from Mazatlan (Lawrence) to Manzanillo (Baird), Tehauntepec (Sumichrast), Tonala (Nelson and Goldman), and Chiapam, Guatemala, January, 1863 (Salvin). A straggler was taken at Santa Lucia, Peru, December 20, 1876 (Taczanowski); there is one record without exact locality for Chile (Hartert); and one bird was taken the winter of 1881–82 in Bermuda (Reid).

Other wandering birds have been collected at Buffalo, N. Y. (Bergtold); Cayuga Lake, N. Y. (Rathbun); Sodus Bay, N. Y., August 28, 1910 (Guelf); Montreal, Canada, October 24, 1888 (Wintle); Toronto, Ontario, May 23, 1890 (Cross), and June 1, 1898 (Fleming); Blencoe, Iowa, October 10, 1894 (Anderson); Lake Koshkonong, Wis., once, July, 1860 (Kumlien and Hollister); Alda, Nebr., July, 1880 (Powell); Kansas, six times (Bunker); Sloans Lake, near Denver, Colo., December, 1889 (Smith); and Fort Wingate, N. Mex. (Coues).

Spring migration.—The first laughing gulls arrive on the coast of Virginia the first of April (Bailey); Cape May, N. J., April 11, 1907 (Hand); and Muskeget Island, Mass., May 7, 1891, May 10, 1892, May 17, 1893, May 9, 1896, May 7, 1898, average May 10 (Mackay). Two wandered inland to Gainesville, Tex., April 10, 1886 (Ragsdale).

April and May are the nesting months on the coast of Venezuela; May and June find the birds nesting in Florida, Jamaica, and Cuba; the earliest eggs taken on the coast of Virginia were on June 3, and the nesting season continues to the middle of July. Here the eggs of the laughing gull are among those gathered regularly for human food. All the eggs are taken systematically until about July 4, after which the birds are left undisturbed to lay another set and raise their young (Bailey). On Muskeget Island, Mass., the earliest eggs were found June 24, 1890, June 7, 1893, June 15, 1894, and June 24, 1898 (Mackay).

Fall migration.—Birds are found returning from the north at Orient Point, Long Island, August 11, 1905, and August 1, 1908 (Latham), and at Charleston, S. C., by August 13 (Wayne). Most of the individuals have left the New Jersey coast by the first of October (Stone), and the last was seen at Nantucket, Mass., October 8, 1907 (Gurley); Springfield, Mass., October 1, 1887 (Morris); Vineyard Sound, Mass., October 4, 1886 (specimen in U. S. National Museum); and Sayville, Long Island, N. Y., October 28, 1880 (specimen in U. S. National Museum).

FRANKLIN'S GULL. *Larus franklini* RICHARDSON.

Range.—Interior of North America from Saskatchewan and Manitoba to the Gulf of Mexico, Middle America, and the western coast of South America to Chile.

Breeding range.—Franklin's gull is more strictly a bird of the interior than any other member of the genus. Its center of abundance while breeding is in the marshy lakes of North Dakota, Manitoba, and Saskatchewan. Here it breeds north to Lake Winnepegosis (Macoun); Quill Lake, Saskatchewan (Barnes); and Many Island Lake, Alberta (Bent). Birds have also been seen north to Hayes River, Keewatin (Saunders); Cumberland House (MacFarlane); Osler, Saskatchewan, May 2, 1893 (Colt); Flagstaff, Alberta, April 24, 1908, and May 4, 1909 (Buswell); and near Edmonton, Alberta, May 11, 1907 (Preble). The species is so erratic in its choice of nesting sites that there is no certainty that any of these latter records represent breeding.

This gull does not breed anywhere east of the Mississippi River, but to the westward it is found south to Heron Lake, Minn. (Roberts); Brookings, S. Dak. (Matheson); Pitrodie, S. Dak. (Cheney); Fort Sisseton, S. Dak. (McChesney); and at Devils Lake, N. Dak. (Eastgate). During the years 1890 to 1893 it nested at Spirit Lake, Iowa (Berry), but it probably does not breed anywhere in that State at the present time.

Winter range.—The species has been taken at Mazatlan, Sinaloa, December (Lawrence); Chiapam, Guatemala, January, 1863 (Salvin); and Panama, December 28, 1855 (specimen in U. S. National Museum); but the real winter home is on the coast of Peru and Chile, from Payta, Peru (Saunders), to Concepcion, Chile (Philippi).

Migration range.—During spring or fall migration Franklin's gull has been taken at Laguna de S. Baltazar, Puebla, September (Ferrari-Perez); near the City of Mexico (Saunders); Zacatecas, August (Saunders); Progreso, Yucatan, fall (Saunders); Port Limon, Costa Rica (Cherrie); and the Galapagos (Snodgrass and Heller). It has occurred accidentally at St. Bartholomew Island, Lesser Antilles

(Sundevall); Blacksburg, Va., October 24, 1898 (Smyth); Licking Reservoir, Ohio, October 15, 1906 (Jones); Hamilton, Ontario, once in April and once in October (McIlwraith); near Philadelphia, Pa., October 22, 1911 (Stone); and near Holland, Mich., April 28, 1897 (Barrows). The species has been widely chronicled—through a printer's error—as an abundant bird in Utah, whereas it is only accidental there, having been noted June 2, 1902, and once in 1906, both at Great Salt Lake (Goodwin).

Spring migration.—That the earliest spring dates for Franklin's gull in the United States should come from Minnesota and South Dakota is remarkable. This is an extreme example of what has been noted in lesser degree with many species—that they appear in their southern breeding grounds, earlier than in the region directly to the south which they must have crossed to reach the summer home. The average date of spring arrival at Heron Lake, Minn., is April 4, earliest March 27, 1889; southeastern South Dakota, average April 7, earliest March 27, 1890; Badger, Nebr., average April 2, earliest March 30, 1900; Wall Lake, Iowa, average April 24, earliest April 19, 1911; eastern Kansas, average April 21, earliest April 10, 1891; eastern North Dakota, average May 1, earliest April 21, 1895; Aweme, Manitoba, average April 25, earliest April 8, 1901; Indian Head, Saskatchewan, average May 3, earliest April 25, 1906.

Some other spring dates are: Monteer, Mo., April 20, 1909 (Savage); Liter, Ill., April 21, 1882 (Griffin); Warsaw, Ill., once, May, 1875 (Ridgway); Keokuk, Iowa, April 6, 1902 (Currier); Elk River, Minn., April 13, 1888 (Bailey); Fort Stockton, Tex., April 24 (specimen in U. S. National Museum); Kerrville, Tex., April 26, 1909 (Lacey); Lincoln, Nebr., April 10, 1899 (Wolcott); Alda, Nebr., April 3, 1884 (Powell); and Brookings, S. Dak., March 22, 1908 (Matheson).

The species was common in Callao Bay, Peru, as late as April 11, 1883 (Macfarlane), while a late date is that of one taken at Champerico, Guatemala, May 30, 1873 (Salvin). Other late spring dates are: Kerrville, Tex., May 17, 1910 (Lacey); Nishna Lake, Mo., May 15, 1909 (Burnett); Wall Lake, Iowa, average date of the last seen, May 24, latest June 27, 1910 (Spurrell); Onaga, Kans., May 11, 1910 (Crevecoeur); Clay Center, Kans., June 6, 1909 (Graves); Hudson, Kans., June 9, 1907 (specimen identified at Biological Survey); and Aransas Bay, Tex., June, but not breeding (Armstrong).

The earliest eggs were found at Heron Lake, Minn., May 25, 1885, May 8, 1886, May 18, 1890, and May 26, 1893 (Miller); near Marsh Lake, Minn., May 16, 1885 (Preston); and eggs heavily incubated, near Crane Lake, Saskatchewan, June 13, 1894 (Macoun). An enormous colony, estimated at 15,000 to 20,000 nests with eggs, was found at Lake of the Narrows, Saskatchewan, June 9, 1905 (Bent). The

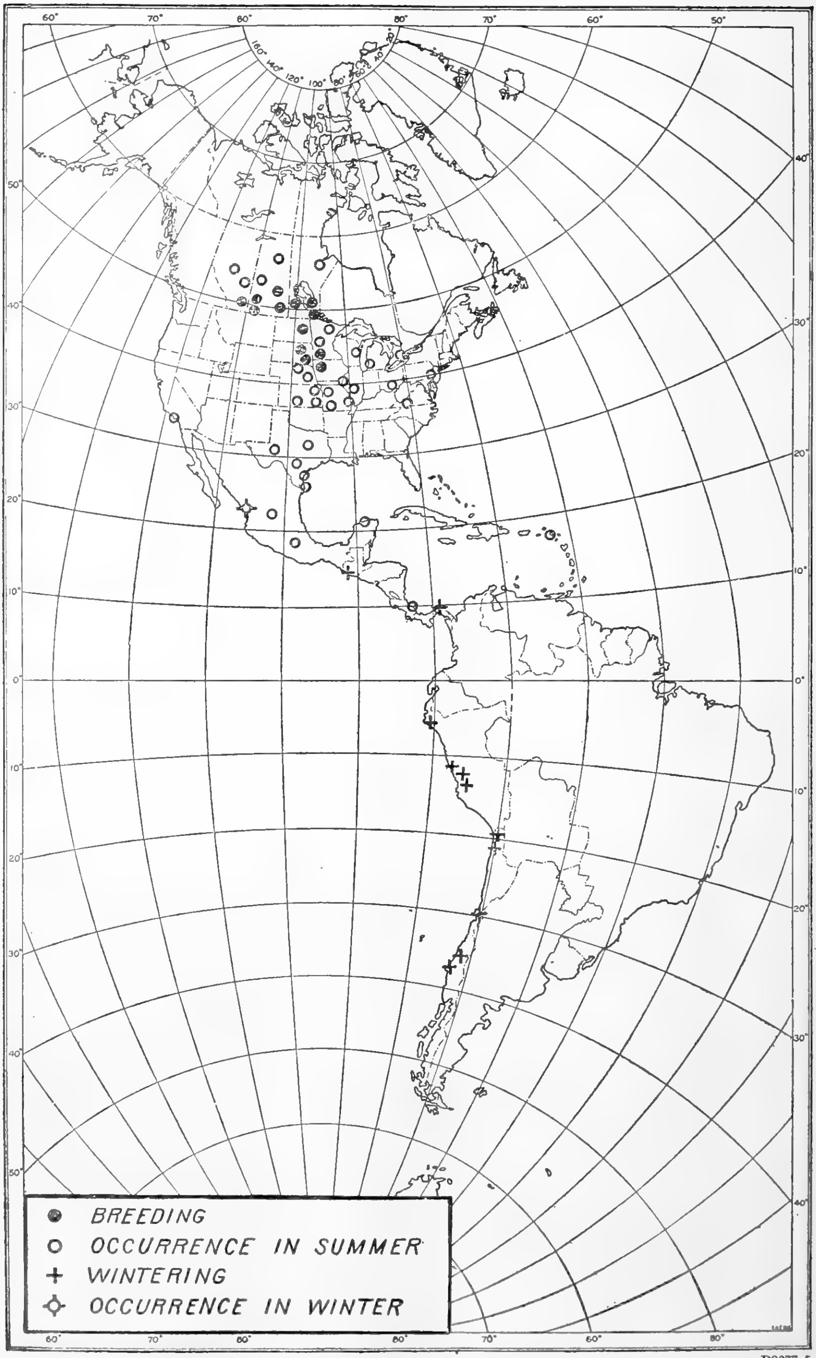

FIG. 26.—Franklin's gull (*Larus franklini*).

next year not a nest could be found at this lake, owing to a drought that had lowered the water level.

Fall migration.—A very early migrant was taken at Valparaiso, Chile, in September, 1859 (Philippi), though usually the species does not reach southern Texas until the last of that month (Armstrong). The extreme northern part of the range is deserted, however, at an early date, since for 14 years the average date of the last one seen at Aweme, Manitoba, is August 10, latest August 21, 1905 (Criddle); Harrisburg, N. Dak., latest October 1, 1901 (Eastgate); southeastern South Dakota, average of the last seen October 13, latest November 12, 1891; Badger, Nebr., November 12, 1899 (Colt); Lincoln, Nebr., November 17, 1900 (Wolcott); Lawrence, Kans., November 1, 1905 (Wetmore); Madison, Minn., October 8, 1894 (Lano); West Depere, Wis., October 22, 1884 (Willard); Lake Koshkonong, Wis., a few each year in September and October, latest October 29, 1871 (Kumlien); and Corpus Christi, Tex., November 3–7, 1909 (Thayer).

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FIG. 27.—Franklin's gull (*Larus franklini*), adult in summer plumage.

BONAPARTE'S GULL. *Larus philadelphia* (ORD.)

Range.—North America from Alaska and Mackenzie to Yucatan and Jalisco, Mexico.

Breeding range.—A distinction needs to be made in the case of Bonaparte's gull between its summer home and its nesting range, since many of this species remain through the summer as nonbreeders far south of the district in which they nest. Eggs or nests or unfledged young have been found at only a few places. This gull breeds abundantly in northern Mackenzie in the region around Fort Anderson (MacFarlane), and thence west to Fort Yukon and the lower Yukon, at Nulato (Dall), the only places in Alaska whence the eggs have been reported. It breeds south to the lakes on the upper Pelly River in Yukon (Pike) and to Atlin in northern British Columbia (Anderson); these five places seem to be the only sure records of actual nesting. Although the species has been reported as nesting at various places south to southern British Columbia, Alberta, Manitoba, southern Keewatin, and even to North Dakota, Minnesota, Wisconsin, and Michigan, it is very suggestive that it is not known

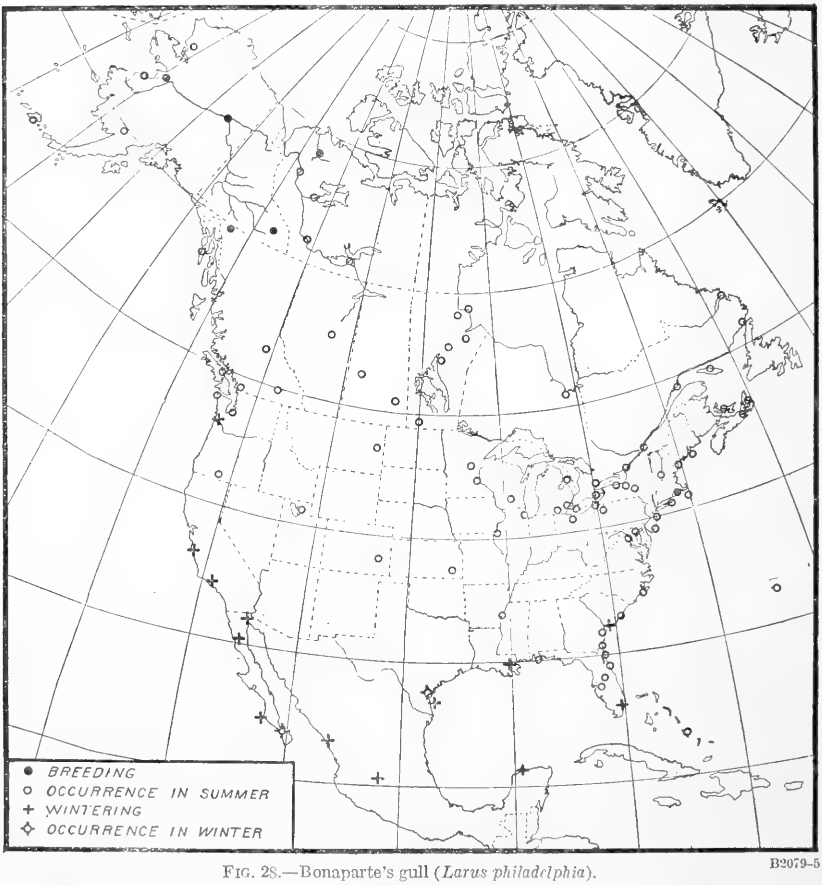

FIG. 28.—Bonaparte's gull (*Larus philadelphia*).

to nest on any of the large lakes in southern Mackenzie, where it would certainly breed if it did at these much more southern localities. The probabilities are that Bonaparte's gull is an arctic- and subarctic-breeding bird which finds its most congenial home on the Arctic lakes and rivers at the farthest north it can find the evergreens on which it places its nest.

During summer, nonbreeding individuals of the species occur commonly on the coast of southeastern Alaska (Swarth) and not rarely on the coast of British Columbia (Kermode). To this same class should probably be referred the birds seen at the north end of Lake Winnipeg, June 15–17, 1900 (Preble), July 7–9, 1900, in southern Keewatin (Preble), and the late June birds of the Bay of Fundy (Brewer). Audubon notes that individuals found to be abundant about the Bay of Fundy in May were birds one year old that on dissection showed they were not to breed that year.

Winter range.—Bonaparte's gull winters regularly and commonly on the coast from Florida to South Carolina, less commonly to Long Island, and stragglers have occurred at this season north to Maine. It winters on the Gulf coast of the United States and on the Pacific coast north at least to southern Washington. On the coast of Los Angeles County, Cal., it winters commonly, and less commonly to San Quintin, Lower California, January 12, 1907 (Thayer); Magdalena Island, Lower California, December 5, 1905 (Nelson and Goldman); Mazatlan, Sinaloa, December, 1896 (Loomis); and to La Barca, Jalisco (specimen identified at the Biological Survey). It ranges in Florida south to Lemon City (Brown), was noted at Progreso, Yucatan, in late January (Cole), and winters at the mouth of the Colorado River (Rhoads).

Migration range.—Breeding in the interior on fresh water, Bonaparte's gull seeks salt water as soon as its family cares are concluded. Although the principal breeding range is in the northwestern part of the American Continent, many more than half of the gulls go eastward in their migration to spend the winter on the Atlantic coast. The line of flight corresponds in general with the northern limit of tree growth, reaching the coast of Hudson Bay in the vicinity of Cape Churchill, and thence passing around its southern end to the Gulf of St. Lawrence; a few individuals occur along the Labrador coast at the Strait of Belle Isle and as far north as Hamilton Inlet (Bigelow). Another numerous group choose a route a little to the southward by way of Lake Winnipeg and the Great Lakes to the Atlantic coast.

Small numbers go south in fall through the Mississippi Valley to winter on the Gulf coast, but only a few choose this route, for Bonaparte's gull is a bird of lakes rather than rivers, and there are few congenial stopping places in the southern half of the Mississippi Valley.

The small contingent electing the Pacific coast for their winter home go directly south, crossing the main divide of the Rocky Mountains to the coast of southern Alaska, whence they follow down the coast to the winter home. A few seem to wander up the valley of Peace River and cross southern British Columbia to the coast.

The same routes seem to be retraced in spring, except that the Atlantic coast birds at this season probably do not go northeast of the western part of the Gulf of St. Lawrenee.

During migration Bonaparte's gull has wandered north to the mouth of the Kowak River, May 18, 1899 (Grinnell); it was taken on Laysan Island, of the Hawaiian Group, December 27, 1912 (Willett); once on Long Island, in the Bahamas, October 8, 1876 (Moore); in Bermuda, January 27 and December 15, 1849, February 24, 1850, and January, 1876 (Reid); and has been recorded at various places in Europe eleven times as an accidental visitant.

Spring migration.—The average date of arrival at Washington, D. C., is March 30, earliest March 25, 1881; Erie, Pa., average April 20, earliest April 13, 1900; Branchport, N. Y., average April 21, earliest April 17, 1905; North River, Prince Edward Island, average May 21, earliest May 10, 1887; Godbout, Quebec, April 27, 1888 (Comeau); Chicago, Ill., average April 14, earliest April 6, 1903—also a few in winter, December 11, 1906, January 1, 1907, and February 4, 1909; Oberlin, Ohio, average April 16, earliest April 8, 1907, and a straggler or wintering bird February 8, 1909; Ann Arbor, Mich., average April 19, earliest April 16, 1911; Keokuk, Iowa, average March 29, earliest March 28, 1895; eastern Kansas, average April 21, earliest April 7, 1890; Madison, Wis., average April 30, earliest April 22, 1904; Minneapolis, Minn., average May 1, earliest April 1, 1882; southern Manitoba, average April 24, earliest April 20, 1905; Indian Head, Saskatchewan, April 27, 1904 (Lang); Osler, Saskatchewan, May 2, 1893 (Colt); near Fort Resolution, Mackenzie, average May 14, earliest May 9, 1904; Fort Simpson, Mackenzie, May 22, 1860, May 12, 1904; Comox, British Columbia, April 11, 1904; Burrard Inlet, British Columbia, April 13, 1889; and Okanogan Landing, British Columbia, average May 1, earliest April 25, 1907.

The latest date at which Bonaparte's gull was noted at Coronado, Fla., was April 9 (Longstreet); St. Joseph, Fla., April 6, 1886 (Evermann); Frogmore, S. C., May 1, 1885 (Hoxie); Charleston, S. C., May 15, 1909 (Weston); Fort Macon, N. C., May 3, 1869 (Coues); Washington, D. C., average May 1, latest May 30, 1884; Erie, Pa., May 15, 1901, and May 25, 1895; Rochester, N. Y., June 8, 1902 (Eaton); Ithaca, N. Y., June 14, 1908 (Reed and Wright); near Newport, R. I., May 22, 1902 (King); Woods Hole, Mass., June 3, 1891 (Edwards); Monomoy, Mass., June 9, 1886 (Cahoon); Penobscot Bay, Me., to June 20 (Knight); New Orleans, La., March 25, 1894 (Beyer); Chicago, Ill., average May 17, latest May 30, 1908; Oberlin, Ohio, average May 20, latest May 31, 1897; Ottawa, Ontario, June 9, 1885 (White); and at Monterey, Cal., rare after May 18, latest June 2 1897 (Loomis).

Eggs were taken at Fort Yukon, Alaska, June 16, 1861 (Kennicott); June 7, 1862 (Dall); and at Fort Anderson, Mackenzie, June 6, 1862, and June 16, 1863 (MacFarlane). Downy young were taken at Hot Springs, Atlin, British Columbia, July 3, 1914 (Anderson).

Fall migration.—The most pronounced characteristic of the fall migration of Bonaparte's gull is its early date of beginning. At Okanogan Lake, British Columbia, the average date of its arrival in southward migration is July 21, earliest July 9, 1911 (Brooks); this species was noted at Lake Iliamna, Alaska, July 16, 1902 (Osgood); a flock appeared at Erie, Pa., July 4, 1909 (Simpson); one at Ithaca, N. Y., July 24, 1908 (Reed and Wright); Portland, Me., July 27, 1908 (Eastman); Chicago, Ill., July 15, 1906 (Armstrong); on the Yellowstone River, Mont., July 31, 1905 (Cameron); and on the Laramie River, Wyo., July 23, 1857 (Knight).

Probably the normal beginning of fall migration is represented by the numerous birds present at York Factory, Keewatin, July 17–22, 1900 (Preble), and the continuation of this movement is is noted at Baddeck, Nova Scotia, August 4–16, 1886 (Dwight); Portland, Me., August 9, 1905, and August 4, 1906; Charlestown, N. H., August 3, 1897 (Buswell); Monomoy, Mass., August 13, 1885 (Cahoon); Point Judith, R. I., August 5, 1900 (Hathaway); Erie, Pa., August 20, 1890, and August 13, 1902; Atlantic City, N. J., August 21, 1892 (De Haven); Charleston, S. C., August 20, 1909 (Wayne); Coronado, Fla., earliest September 16 (Longstreet); Chicago, Ill., average August 21, earliest August 17, 1907; Oberlin, Ohio, average September 4, earliest August 11, 1910; Moose Factory, Ontario, August 11, 1860 (specimen in U. S. National Museum); Toronto, Ontario, August 4, 1890 (Fleming); Ottawa, Ontario, August 24, 1887 (White); Delavan, Wis., August 26, 1892 (Hollister); southern Manitoba, average August 31, earliest August 15, 1899; and on the coast of Los Angeles County, Cal., common after August 20, 1910 (Willett). The foregoing dates are the records of a comparatively few individuals, most probably nonbreeders or those that lost their eggs or young. The great bulk of the birds move a month to six weeks later. They are most numerous along the New England coast in October and reach the coast of southern California in early November.

The average date of the last one seen at Montreal, Canada, was September 26, latest October 1, 1892 (Wintle); North River, Prince Edward Island, average November 20, latest November 25, 1888 (Bain); Woods Hole, Mass., December 23, 1892 (Edwards); near Oberlin, Ohio, December 17, 1906, and January 6, 1908 (Jones); Toronto, Ontario, November 25, 1898 (Nash), and December 15, 1897 (Fleming); Birch Lake, Alberta, October 13, 1909 (Brooks and Cobb); Fort Good Hope, Mackenzie, as late as October, 1864 (specimen in U. S. National Museum); Margaret, Manitoba, average October 19, latest October 24, 1910 (Black); Aitken, Minn., November 2, 1902 (Lano); Lincoln, Nebr., November 3, 1896 (Bruner); Pueblo, Colo., November 15, 1895 (Nash); Unalaska Island, Alaska, October 4–5, 1899 (Bishop); southwestern British Columbia, average November 5, latest November 29, 1888; and Klamath Lake, Oreg., November 7, 1909 (Lewis).

[**LITTLE GULL.** *Larus minutus* PALLAS.

The little gull is only a straggler in North America. Its regular summer home is in northern Europe and northern Asia, whence it retires in winter as far south as the Mediterranean and the Adriatic. It is found at this latter season in northern Africa and in northern India. Its claim to a place in the North American list rests on a few specimens taken at widely separated times and places: Bermuda, January 22, 1849, and one in February, 1849 (Wedderburn); Fire Island, Long Island, one about September 15, 1887 (Dutcher); Rockaway Beach, Long Island, one May 10, 1902 (Braislin); and Pine Point, Scarborough, Me., one July 20, 1910 (Norton).]

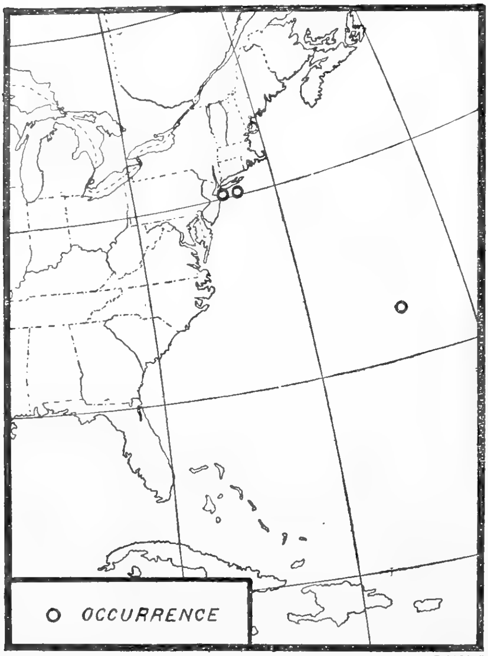

FIG. 29.—Little gull (*Larus minutus*).

ROSS'S GULL. *Rhodostethia rosea* (MACGILLIVRAY).

Range.—Arctic regions of both hemispheres in summer; winter home unknown.

The first eggs known to science of Ross's gull were taken June 13, 1905, at Pokhodskoe, near the center of the delta of the Kolyma River, Siberia (Buturlin). They were already incubated, but incubation could not have been far advanced, for the first arrival, a single bird, was not seen until May 30, though the species became common the next day. Eggs nearly hatched were collected June 26, and young 2 to 3 days old on July 1. Eggs were also taken June 13 at Malaya, about 150 miles to the westward of Pokhodskoe. The birds were equally common in this region in 1911 and nested in large numbers in swamps north of the town of Nijni Kolymsk, in the upper part of the delta, latitude 68° N., longitude 161° 30′ E. The next season the whole coast was searched, from these swamps to the northern end of the delta and along the Arctic coast eastward for 150 miles to Chaun Bay, but not a breeding colony could be found; one stray individual was taken May 3, 1912, at Nijni Kolymsk (Thayer and Bangs).

During Buturlin's stay at the mouth of the Kolyma River he paid particular attention to Ross's gull and obtained definite information in regard to the extent of its breeding range. It is known to breed northwest to Russkoe Ustje, in the delta of the Indigirka River, latitude 71° N., longitude 149° E.; southwest to Abyi, near the Indigirka River, about 300 miles inland from the Arctic coast, latitude 67° 30′ N., longitude 145° E.; northeast to the northeastern part of the Kolyma delta near the Arctic coast, latitude 69° 30′ N., longitude 161° E.; and southeast to Sredne-Kolymsk, on the Kolyma River, about 200 miles from its mouth, latitude 67° 30′ N., longitude 155° E. The breeding range extends, therefore, through 3½ degrees of latitude and 16 degrees of longitude, covering an area a little less than 300 miles square. The species has not been found breeding on any of the Arctic islands either east or west of the Kolyma

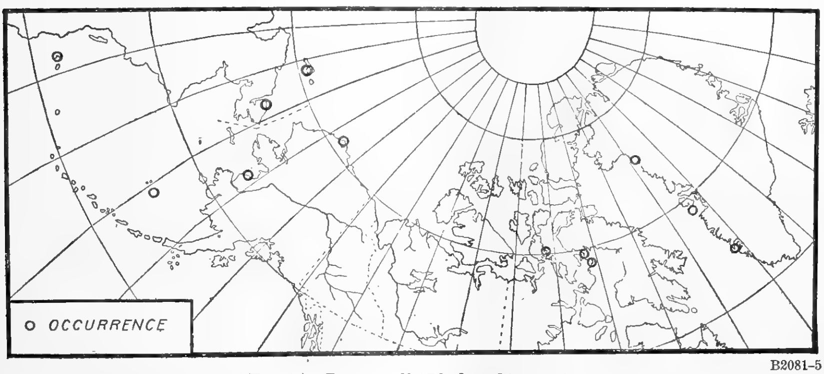

FIG. 30.—Ross's gull (*Rhodostethia rosea*).

delta, but all these islands are rocky, while Ross's gull is exclusively a marsh breeder.

An interesting habit of this gull is its early desertion of its breeding grounds. Only 20 days after the first egg hatched, both old and young left the interior of the delta, and four days later the last one disappeared from the coast at the mouth of the river.

If the 60,000 square miles near the mouth of the Kolyma River really comprise the only nesting place of this gull, then many non-breeding individuals must spend the summer far from the breeding grounds. The type specimen was taken in the height of the breeding season, June 23, 1823, at Alagnak, Melville Peninsula, near Igloolik (Ross). A second was seen there four days later, but the birds were certainly not breeding anywhere in this region, for these are the only individuals recorded in the vast stretch of 2,000 miles between Greenland and Point Barrow. Birds presumably non-breeders were noted by naturalists of the *Jeannette* just west of Wrangell Island, June 22–30, 1880; one at Pitlekaj, July 1, 1879

(Nordenskiold); just north of Bennett Island, in July, 1881 (De Long); in the delta of the Lena River, July 8, 1883 (Bunge)—the conditions here are so similar to those of the nesting site that it would not be surprising if eventually the bird should be found breeding in the Lena Valley; Hvidtenland, just east of Franz Josef Land, earliest July 14, 1895, common the next day (Nansen); Disco, Greenland, June 15, 1885 (Seebohm); and Point Barrow, Alaska, June 9, 1898 (Stone). The last two records are probably of stragglers, but the others would indicate a summer nonbreeding range on the Arctic coast and islands from longitude 173° W. to longitude 63° E., nearly 2,000 miles in this latitude.

The most extensive migrations occur in September and the most notable of these so far recorded are those witnessed by Murdoch at Point Barrow. Here the first birds were seen September 28, 1881, and the species was common for a month, literally thousands passing, all going toward the northeast. A similar flight was witnessed the next year, when the species was abundant from September 10 to October 9. When the same place was visited in the fall of 1897, only two individuals were seen, one on September 9 and the other September 23 (Stone). Similar flights of large flocks of the birds were seen by Birulia, near the New Siberian Islands, in 1901 and 1902. Young birds of the year were abundant September 11, 1901, near Bennett Island, and the next year flocks of young appeared at New Siberia August 16, followed by flocks of old birds September 5. After this both were abundant September 11–15, and disappeared September 20.

Northeast of the New Siberian Islands, in about latitude 81° N., Nansen saw 8 birds in early August, 1894, during the drift of the *Fram*. The naturalists of the *Jeannette* saw them in October, 1879, near Wrangell Island, and on October 10, 1879, a lone individual appeared at St. Michael, Alaska (Nelson).

The winter home of Ross's gull is entirely unknown. Stragglers have been taken at this season on Bering Island, December 10, 1895 (Stejneger); two at Cagliari Bay, in the Sardinian Sea, in early January, 1906 (Martorelli); one at Pointe de la Roche, on the coast of Vendée, France, December 22, 1913 (Sequin); one on Suderoe Island of the Faroe group, February 1, 1863 (Müeller); and one on Helgoland, February 5, 1858 (Gatke). Even stragglers have not been noted anywhere during March and April or before late May, when the birds arrived at their breeding grounds in the delta of the Kolyma River, and were also noted in migration at Verkhojansk, on the Java River, 250 miles from the coast and about the same distance west of the most western known breeding colony. Inhabitants of this latter place reported that visits of this gull were unusual and that it did not breed in that district. Another spring bird, but evidently a wanderer, was taken on St. George Island. Alaska, May 25, 1911 (Evermann).

In the 35 years following discovery of this species only two individuals were seen, one in latitude 82°, north of Spitzbergen, about 1827 (Ross), and one at Felix Harbor in either 1830 or 1831 (Ross). During the next 20 years only about 10 additional birds were seen, and then in the three years from 1879 to 1882, the real home was found and the birds were seen by hundreds.

In addition to the records given in the foregoing, Ross's gull has been taken on the west coast of Greenland about six times, from Sukkertoppen to Melville Bay (Schalow); north of Spitzbergen in midsummer, about latitude 84° 40′ (Sverdrup)—the most northern record to date; near Franz Josef Land, one in 1873 (Payer); two in Kamchatka (Saunders); and one in Yorkshire, England (Saunders).

SABINE'S GULL. *Xema sabini* (J. SABINE).

Range.—Arctic regions of both hemispheres, south to South America.

Breeding range.—Eggs of Sabine's gull have been taken in only a few localities, but these are scattered across the Arctic coast from Greenland on the east to the mouth of the Yukon on the west, about a hundred degrees of longitude. Then comes a space of a hundred degrees in which the species is not known to breed, and then a large colony of nesting birds is recorded from the Taimyr Peninsula in northwestern Siberia (Middendorff), with no other known breeding place within 2,000 miles in either direction. It is evident that the real summer home of the species is in the Arctic regions of the Western Hemisphere and that the breeders on the Siberian coast must be considered a sporadic colony.

The type specimen was taken in latitude 75° 30′ in Melville Bay, on the west coast of Greenland, July 25, 1818 (Sabine), where the species was common and young were just hatching. The most northern breeding record on this coast is at Thank God Harbor, latitude 81° 40′, where a bird was taken containing an egg just ready to be laid (Davis). To the westward the breeding range is much farther south, since eggs were taken in latitude 63°, on Southampton Island in Hudson Bay during the summer of 1904 (Low). Eggs were found by Collinson at Cambridge Bay, and the species is common to abundant as a breeder on the shores of Liverpool and Franklin Bays, Mackenzie (MacFarlane). It has not been found nesting on any of the Arctic islands in either hemisphere, though it was taken north to Walker Bay (Collinson), Wellington Channel (Sutherland), and Prince Regent Inlet (Sabine). It was found common at Igloolik, on Melville Peninsula, but apparently did not breed near there. Nor is it certain that it nests at Point Barrow, where

Murdoch, Seale, and McIlhenny found it common in migration. It breeds commonly at the mouth of the Yukon and on the shores of Norton Sound and south along the Alaska coast to the mouth of the Kuskokwim (Nelson).

Winter range.—The only place where Sabine's gull has been found in winter is on the coast of Peru. Here it is common in Callao Bay from December (Markham) to April (Macfarlane). It was also taken

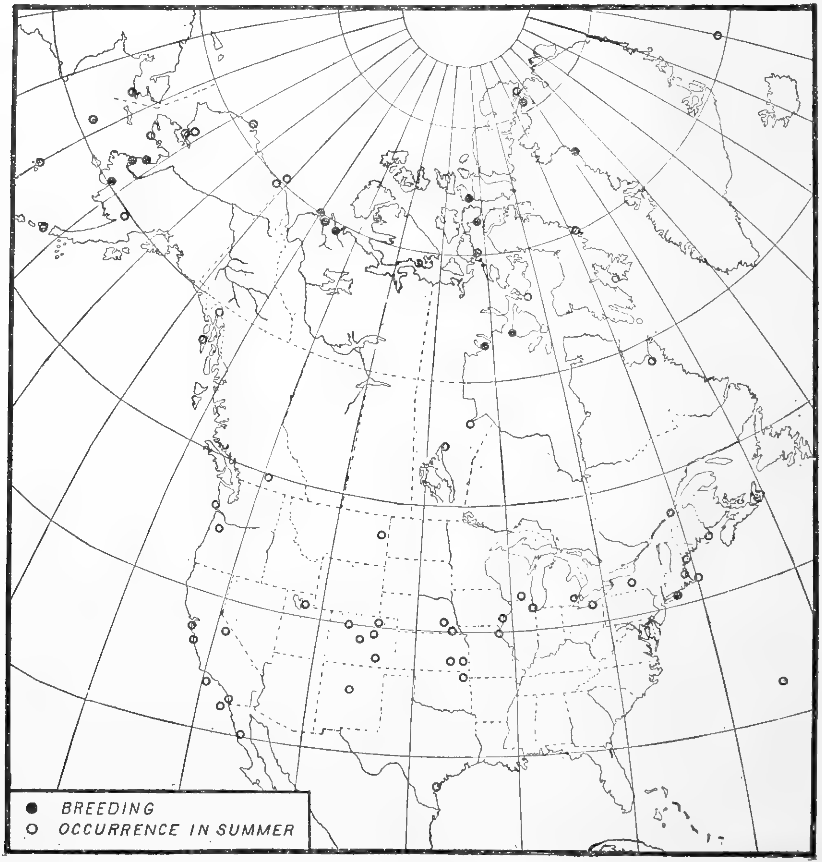

FIG. 31.—Sabine's gull (*Xema sabini*).

at Tumbez, on the extreme northern coast of Peru, in September, 1872 (Steere). Except as single birds have been found wandering far inland, the record for Callao Bay is the only known occurrence of the species for half the year, from October to April. Whenever the winter home of Ross's gull is discovered Sabine's gull will probably be found there also, for the two species arrived together at the mouth of the Kolyma River, Siberia, the first of June, 1905 (Buturlin), and were together when seen in migration in May several hundred miles west of that district (Buturlin).

Migration range.—During both spring and fall Sabine's gull occurs regularly on the Atlantic and Pacific coasts of the United States and has also wandered inland so many times that there are records of it from most of the States of the Union. There are no Mexican, Central American, or West Indian records, except a few on the western coast of Lower California, and no record on the whole coast of the United States from Long Island to Texas. The bird is known from Spitzbergen, Jan Mayen, the coasts of the North Sea, and inland to Austria-Hungary, and Lake Geneva, Switzerland. It is a fairly common fall migrant on the coast of Siberia, at Plover Bay (Dall), and was once collected at Novo Marinsk at the head of the Gulf of Anadyr (Allen).

Spring migration.—The earliest dates of arrival at St. Michael, Alaska, were May 7, 1851 (Adams), and May 10, 1878 (Nelson), and the species became common there May 15–25. The first were seen at Point Barrow June 2, 1882, and June 6, 1883 (Murdoch), and the first at Camden Bay, Yukon, May 13, 1854 (Collinson). The fact that the species was still common in April at the southern limit of its range, in Peru, would seem to indicate that it remains in its winter home until the breeding season is near at hand and then performs a late and rapid migration.

During the period of spring migration the species is rarely noted in North America south of the breeding grounds, and has been recorded from Scarborough, Me., May 31, 1877 (Smith); Indian Head, New Brunswick, May, 1878 (Boardman); Chicago, Ill., April 1, 1873 (Nelson); near Janesville, Wis., April, 1897 (Hollister); near Norway House, Manitoba, June 11, 1859 (Kennicott); Cumberland Gulf, June 15, 1884 (Henderson); Winter Island, Melville Peninsula, June 29, 1822 (Parry); Fort Conger, Ellesmere Island, July 6, 1882 (Greely); San Diego, Cal., May 15, 1905 (Nelson and Goldman); Monterey, Cal., several, April 9, 1903 (Breninger); one, May 12, 1897 (Loomis), and 11 birds, May 15–21, 1907 (Beck); near Bellabella, British Columbia, several, May 24, 1911 (Wetmore); and Chilkat Inlet, Yukon, one, June 1, 1899 (Osgood).

The earliest eggs at St. Michael, Alaska, were laid June 5; by June 13, 1880, full complements of eggs were common; and the earliest young were on the wing July 15–20 (Nelson). Eggs were just hatching in Melville Bay, Greenland, July 25, 1818 (Sabine), while eggs were taken on Southampton Island, Hudson Bay, June 28, 1908 (Low), and young were already on the wing at Point Dalhousie, Mackenzie, August 8, 1848 (Richardson).

Fall migration.—Evidently some individuals start southward before the normal ending of the breeding season, for the first fall migrants have appeared at St. Matthew Island, Alaska, July 15, 1899 (Fisher); near mouth of Georges River, Ungava Bay, middle of July, 1884 (Turner); Raynor South, Long Island, N. Y., July, 1837 (Giraud);

while in 1907 the first fall migrants appeared at Monterey, Cal., July 22 (Beck), and were thus 2,000 miles south of the nesting grounds at the time the earliest young were just learning to fly. In other years the first appeared in August: Santa Cruz Island, Cal., August 6, 1909 (Wright); Monterey, Cal., August 23, 1894 (Loomis); near Los Coronados Islands, Cal., August 20, 1910 (Wright); Unimak Island, Alaska, August 14, 1901 (McGregor); St. Lawrence Island, Alaska, August 29, 1879 (Nelson); San Quintin, Lower California, August 14, 1905 (Nelson and Goldman); and North Truro, Mass., August 21, 1889 (Miller).

In the interior Sabine's gull has been taken at Cayuga Lake, N. Y., about 1887 (Eaton); on the Mississippi River opposite Clark County, Mo., September, 1900 (Worthen); once at Cleveland, Ohio (Winslow); Ann Arbor, Mich., November 17, 1880 (Covert); Burlington, Iowa, October 15, 1891, and October 12, 1894 (Bartsch); Delavan Lake, Wis., October 7, 1900 (Hollister); Big Lake, near Claremore, Okla., November, 1910 (Strode); Humboldt, Kans., September 21, 1876 (Snow); Beatrice, Nebr., September 2, 1899 (Swenk); Lincoln, Nebr., near, September 30, 1899 (Carriker); Albuquerque, N. Mex., October 7, 1900 (Birtwell); Ogden, Utah, September 28, 1871 (Allen); Terry, Mont., several, September 22–23, 1904 (Cameron); Corvallis, Oreg., September 14, 1904 (Shaw); Mono Lake, Cal., September 18, 1901 (Fisher); and Okanogan Lake, British Columbia, September 9, 1897 (Brooks). It is somewhat strange that there should be about as many records of Sabine's gull in Colorado as in all the rest of the interior. Most of them are between September 3 and November 17, and come from the western edge of the plains from Fort Collins to Denver, but one was taken September 26, 1886, in the mountains near Breckenridge at 10,000 feet altitude (Carter).

The last seen at St. Michael, Alaska, was on October 10, 1879 (Nelson); Point Barrow, Alaska, October 22, 1881 (Murdoch), and September 17, 1897 (Stone); Kowak River, Alaska, September 5, 1898 (Grinnell); Sea Island, Shoalwater Bay, Wash., September 24, 1897 (Dawson); San Francisco Bay, Cal., October, 1889 (Bryant); Monterey, Cal., October 5, 1899 (Loomis), October 28, 1907, and October 6, 1909 (Beck); Igloolik, Melville Peninsula, August 13, 1822 (Parry); Kikkerton Island, Greenland, October 6, 1877 (Kumlien); near Portland, Me., September 22, 1899 (Knight); Boston Harbor, Mass., September 27, 1874 (Brewster); Gardiners Bay, Long Island, October 6, 1899 (Worthington); Quebec City, Canada, about October 1, 1909 (Dionne); and Corpus Christi, Tex., October (Armstrong).

INDEX.

R.

S.

T.

V.

X.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 293

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER October 7, 1915

THE GRASSHOPPER OUTBREAK IN NEW MEXICO DURING THE SUMMER OF 1913.[1]

By Harrison E. Smith,

Entomological Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

Of the several important grasshopper outbreaks in the United States during the summer of 1913 that of the so-called long-winged

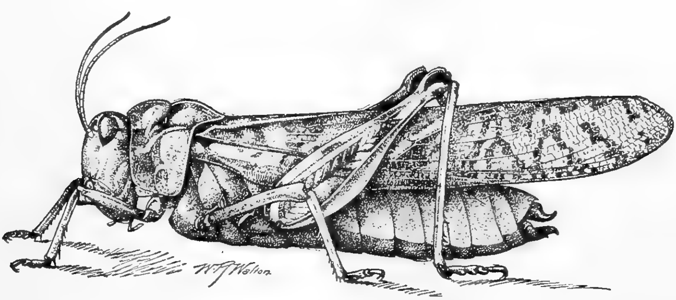

Fig. 1.—Long-winged grasshopper (*Dissosteira longipennis*): Adult female. About one-third enlarged. (Original.)

grasshopper (fig. 1) in the Pecos Valley of New Mexico proved one of the most interesting. Though more or less important outbreaks of this grasshopper have been reported heretofore, very little actual data pertaining to this species appears to have been assembled.

The writer, under the direction of F. M. Webster, in charge of cereal and forage insect investigations of the Bureau of Entomology, spent the month of June, 1913, in the field investigating this rather unusual invasion.

The data are of necessity in certain phases somewhat incomplete since the investigations were carried on entirely under field conditions, although a very considerable amount of information relative to this species was obtained and is herein presented.

[1] The grasshopper discussed in this paper is scientifically known as *Dissosteira longipennis* Thomas; synonym, *Oedipoda nebracensis* Bruner.

HISTORY IN AMERICA.

This long-winged grasshopper was originally described by Cyrus Thomas in 1872 under the name of *Oedipoda longipennis*, from a male specimen, marked "Kansas," submitted to him in a collection from the Agricultural Department. C. V. Riley claims to have collected this species in Colorado on his first trip to that State in 1867.

In 1876 S. H. Scudder proposed a new genus (Dissosteira) for the reception of *Oedipoda longipennis* Thom. and *Gryllus carolina* Linn., designating the latter species as the genotype.

In 1875 Philip R. Uhler found this species in small numbers in the region west of Colorado Springs, Colo.

In 1891 Lawrence Bruner, while upon a general tour of observation to investigate rumored grasshopper ravages in different parts of the Western States, stated that the species causing the alarm in Colorado was "* * * a rather rare species, known as *D. longipennis*, it occurring at that time over 400 sq. miles of territory in sufficient numbers to materially injure the grasses growing on the range of the entire region. Grains and other cultivated plants did not appear to be especially attractive to it. In fact, very little or no injury was done by it to the cultivated crops growing within the region infested."

Between July 10 and 19, 1891, the late E. H. Popenoe visited Lincoln County, Colo., where grasshoppers of this species were so numerous as to stop the trains.

In 1892 Kellogg stated that this species was locally hurtful in Kansas, but that no serious crop destruction was threatened. He stated further, "* * * This locust is a nonmigratory form, occasionally abundant on the plains of eastern Colorado. It sometimes occurs in sufficient numbers in restricted areas to destroy all vegetation."

In 1895 Bruner noted this species "* * * Out on the plains away from the foothills and irrigating ditches," as quite abundant over a large portion of Colorado and Nebraska. He believed "* * * stony hillsides furnished a suitable place for the increase of *D. longipennis* and several other barren-ground species."

In 1896 Bruner again noted this species abundant in Colorado and Nebraska, recording it attacking and actually destroying entire fields of small grains, some corn, potatoes, and a number of garden plants.

In 1898 this species was occasionally noted in western Kansas by S. J. Hunter, who stated that in Edwards County this locust was abundant in a portion of an alfalfa field of 320 acres. This was first observed July 6. On September 1 females of this species were seen ovipositing in this field. It was his opinion that this colony was bred and reared upon this ground. In the same year he also recorded: "On the evening of July 21 the locusts came from the west down into Colorado Springs in countless numbers."

In 1900 this insect invaded the town of Las Vegas, N. Mex., in great numbers and crushed specimens were everywhere seen on the sidewalks.

In 1904 Bruner wrote, regarding this species, "A native of the high prairies of western Kansas, Nebraska, eastern Colorado, and Wyoming; not nearly so abundant as it was five years ago."

The 1913 outbreak of this species extended over 400 to 500 square miles, the prairie grasses, grain, and garden crops within this area being in great part devastated. Herds of cattle usually grazing within this infested area were forced to travel from 11 to 13 miles for grazing facilities, and would return to their usual watering places only at intervals, varying from 24 to 56 hours. Freight and passenger trains were repeatedly stopped by grasshoppers massing upon the railroad tracks, this being frequent from the middle of May until the first of July.

The prairie grasses within the infested area were so completely ravaged that hardly a surface depression of the soil could be located which was not from one-fourth to completely filled with grasshoppers' droppings.

DISTRIBUTION.

This species is native to the western United States. Since Thomas described the species from western Kansas it has been found in Colorado, Wyoming, Nebraska, Idaho, New Mexico, Texas, and Oklahoma.

SEASONAL HISTORY.

The eggs of this species in New Mexico evidently commence to hatch en masse during the first week of May, though a few nymphs may probably appear during the latter part of April.

Adults were first noted on June 4, and by June 24 the majority of the grasshoppers were in the adult stage. However, third and fourth stage nymphs were present in numbers up to the second week in July.

So far as known, this species has but a single generation per year, the eggs being deposited during late August and early September.

A MIGRATORY OR NONMIGRATORY SPECIES?

In 1892 Kellogg stated that in Kansas this grasshopper is a nonmigratory species.

In 1913, from May 4 to June 24, nymphal droves of this species traveled in a northeasterly direction some 15 to 18 miles, ravaging the entire growth of prairie grasses in their path.

The species is gregarious, the early maturing adults remaining with the nymphal droves until the majority have attained the fully-winged state.

The adults are readily attracted to lights, having been taken at Clovis, N. Mex., during June, 1913, about 25 miles north of Elida, where the main nymphal droves were located at the time.

In the winged state these insects are very wary and are exceptionally strong fliers.

ORIGIN OF OUTBREAK.

This outbreak originated from a tremendous swarm of adults flying from some unknown point to the north. These settled in the outlying districts of Elida, N. Mex., during the latter part of August and early September. During one evening, when swarms of this species were passing over Elida, large numbers of them flew against the plate-glass window of a brilliantly lighted barber shop. The following morning several bushels of dead grasshoppers were heaped on the sidewalk.

BREEDING GROUNDS.

The breeding grounds on which these swarms settled to deposit their eggs were in most part in a chain of sandhills running from about 8 to 10 miles northwest to southwest of Elida. Another considerable swarm settled and deposited eggs in the sandhills 6½ miles southeast of Elida.

On May 4, 1913, at a point 8 miles northwest of Elida, Mr. B. W. Kinsolving noted the tiny grasshoppers coming out of the sand "by the million." Watching this area for a little over a week Mr. Kinsolving says: "Tiny hoppers appeared to be coming out of the sand continually. One evening during a heavy shower certain areas of this breeding ground were covered at least 6 inches deep with tiny hoppers."

On May 6, 1913, 6½ miles southeast of Elida, Mr. Bruce Marsh noted the tiny grasshoppers issuing from the sand in an area nearly 1 mile square, "the ground over this area appearing like a living mass of crawling maggots."

At about the same time the cowboys on the Littlefield ranch, 8½ miles southwest of Elida, noted the sand moving up and down over a great area. When examined they found "countless millions of tiny hoppers crawling to the surface."

Though the major portion of the egg pods were deposited in the sandhills during the fall of 1912, the writer was informed by several parties that some of the eggs, at least, were deposited in hard land. This is very probably true, but at best they constituted a very small percentage.

METHODS OF TRAVEL.

Grasshoppers of this species appear to have a decided preference for massing together and traveling over barren areas, such as roadways, footpaths, and along railroad tracks and right of ways. Over such areas, under favorable weather conditions, immense droves 1 or 2 miles in length, massed closely together, travel along at a rapid gait, all generally traveling in the same direction. Though large droves mass and travel over the prairie proper, the rate of travel is somewhat less than that of the droves passing over barren areas.

Grasshoppers in the third nymphal stage travel at the rate of from 8 to 12 feet per minute; those in the fourth instar from 15 to 20 feet per minute. The rate of travel of nymphs in the first two instars is proportionally less. Nymphal droves of these grasshoppers, under proper weather conditions, travel from 1 to 2 miles a day.

Adults taking flight during a heavy wind fly with the wind, though generally facing it during the rise from the ground to the desired altitude, which usually is from 30 to 40 feet. Adults have been noted to alight on the surface of water and then easily take wing therefrom.

WEATHER CONDITIONS.

Weather conditions are a very important factor in the dispersion of the grasshoppers, at least during that period when the majority are in the nymphal stages.

Throughout the month of June, 1913, the amount of precipitation in New Mexico was greatly in excess of normal.

On dark, cloudy days or during rainy weather the grasshoppers travel very little. Under such conditions they generally collect beneath available shelter, or mass upon the prairie to feed, or slowly wander around with no apparent object in view. If, however, during one of these periods the sun breaks through the clouds to shine brilliantly for a few moments, every individual becomes active and almost immediately the entire drove is rapidly moving along its usual course of travel. The moment the sun disappears travel ceases as promptly as it began, and the former state of inactivity is soon restored.

During fair, bright sunny weather travel usually commences early in the forenoon and continues until the latter part of the afternoon.

Under high prevailing wind conditions the grasshoppers will seek the windward side of any available shelter, there to remain until the wind has ceased or considerably abated.

FEEDING HABITS.

The major portion of the feeding takes place during the early morning hours and the last part of the afternoon, although intermittent feeding is indulged in throughout the day. Under favorable weather conditions the approximate hours of feeding are from daylight until 8 or 9 o'clock in the forenoon, and from 3 to 4 o'clock until sundown during the afternoon. Apparently little or no feeding takes place during the night. The foliage may be entirely devoured or irregular patches cut out from the margin of the leaves. The stems or stalks may be partly or entirely girdled and cut off.

FOOD PLANTS.

Grama grass (*Bouteloua oligostachya*), buffalo grass (*Bulbilis dactyloides*), and mesquite grass (*Bouteloua hirsuta*) are by preference the most relished food plants of this species. Fields of maize, kafir corn, and millet were completely devastated. Millet is in all instances a most desirable food plant. Mr. Hobson, of Elida, informed the writer that he noted the grasshoppers massing in 5 acres of millet on his farm, and in less than 30 minutes every plant had been eaten to the ground. Sorghum is fed upon to a slight extent, but is seldom disturbed if other more desirable food plants are readily available.

Truck crops in the infested area were entirely defoliated, including the following plants: Cultivated mustard, radish, lettuce, squash, sweet potato, young white potato (old plants seldom disturbed), tomato, sweet corn, and immature onion plants.

Under certain conditions Russian thistle (*Salsola tragus*) is readily fed upon, and slight feeding upon soapweed (*Chlorogalum pomeridianum*) has been noted.

Though S. J. Hunter has recorded this species as being abundant in part of a 320-acre tract of alfalfa in western Kansas during 1898, nymphs of this species forwarded to the Wellington, Kans., laboratory, and confined in a Comstock cage placed over alfalfa plants, failed to display any desire for feeding upon this plant, the nymphs ultimately dying from apparent starvation.

PREDACIOUS ENEMIES.

Among the more important bird enemies noted to be feeding upon grasshoppers during this invasion were the desert horned lark (*Otocoris alpestris leucolaema*), western meadowlark (*Sturnella neglecta*), desert sparrow hawk (*Falco sparverius phalaena*), nighthawk (*Chordeiles virginianus*), killdeer (*Oxyechus vociferus*), and quail (*Colinus virginianus*). The results of further investigations in cooperation with the Biological Survey on the destruction of grasshoppers by birds in New Mexico will be published in another connection.

Several species of lizards, which were very numerous in this locality, fed voraciously upon the nymphs. Oftentimes lizards were noted so bloated from grasshopper feeding that travel was accomplished only with great difficulty. Horned toads were also heavy feeders upon the immature grasshoppers.

While the large droves were passing through the prairie-dog towns these animals appeared to feed upon the grasshoppers in numbers.

PARASITIC ENEMIES.

A dipteron, *Sarcophaga kellyi* Ald., was found to be by far the most important factor in the control of this species, and it was equally efficient as a parasite upon both the nymphs and adults.

Larviposition by the female of *S. kellyi* was continually noted throughout the month of June. The female, as far as observed by the writer, always chose individuals freshly molted or inactive, but in an apparently healthy condition.

During the latter part of June the grasshoppers were enormously reduced in numbers from parasitism by *S. kellyi.* It was a simple matter to count 15 or more dead grasshoppers to the square foot over large areas. The grasshoppers died in such numbers in some localities that ranchers informed the writer that certain droves were almost completely destroyed.

On June 16 a female of *S. kellyi* was noted to deposit tiny maggots on the dorsum of the thorax (pronotum) of a freshly molted nymph. This nymph was captured as the fly finished the act. The fly in question was then noted to rest upon the thorax of a second nymph, where it commenced to larviposit. At this time, while in the act of depositing a maggot, she was captured, and, although badly crushed, the specimen was not so greatly disfigured but that comparison with previously reared specimens proved beyond a question that all were identical. Careful comparison of this female taken in the act of larviposition, with another female noted to be larvipositing in the same manner, but not captured while in the act, proved again that both were the same species.

From the captured nymph above noted six specimens of *S. kellyi* were reared.

This was the only female which the writer was able to capture in the act of depositing the tiny maggots, but it abundantly determined the method of larviposition utilized by *S. kellyi* in parasitizing *D.*

longipennis. Sarcophagids were continually noted to larviposit on nymphs left comatose upon the open prairie, after having been stung by a wasp (*Priononyx atrata* Lep.). In not a single instance was it possible to note a sarcophagid endeavoring to strike a moving nymph or flying adult.

When large numbers of the grasshoppers were molting at approximately the same time the familiar noise of hundreds of female sarcophagids in search of their victim was easily heard. Hot, sunny weather greatly stimulated the activities of the flies, as well as those of the grasshoppers, whereas cold, cloudy, or rainy weather invariably checked them.

The female, upon locating a suitable victim, was observed to alight upon the dorsum of the thorax and quickly deposit several living maggots, which, encountering only the soft, tender membrane, speedily made their way into the body cavity of their host. The maggots are capable, however, of entering a host which is fully dried out and hardened, the writer having noted a female sarcophagid to larviposit on a grasshopper nymph (fig. 2) which had been stung by *Priononyx atrata* and left upon the open prairie beside the partially excavated hole of the wasp; the maggots deposited soon entering the host and the puparia later emerging, to give issuance to adults of *S. kellyi*.

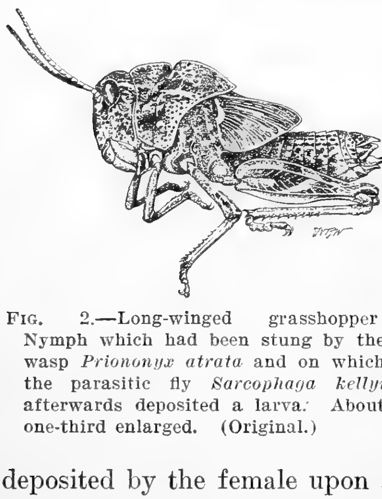

FIG. 2.—Long-winged grasshopper: Nymph which had been stung by the wasp *Priononyx atrata* and on which the parasitic fly *Sarcophaga kellyi* afterwards deposited a larva. About one-third enlarged. (Original.)

The number of living maggots deposited by the female upon an individual host during one period of larviposition would vary from 1 to 7 or more, although from 3 to 6 appeared to be the more general. The writer has reared individuals from five puparia of *S. kellyi* taken from an adult of *Dissosteira carolina* captured at Wellington, Kans., on the wing July 9, 1913, the maggots emerging from the host July 10. As many as 16 maggots have been found in the body cavity of a large nymph of *Hippiscus* sp. in New Mexico.

The maggots of *S. kellyi* usually issue from their host just posterior to the anterior coxa. A certain percentage, however, depart from the host by boring through the abdomen at the segmental sutures or by passing through the anal orifice. Upon leaving the host the maggots may enter the soil directly beneath their victim, or they may crawl several feet away before entering the ground. The summer generations of *S. kellyi* pupate from one-half to 2 inches below the soil surface, but very probably the maggots or puparia of the hibernating fall generation enter the soil to a much greater depth.

Sarcophaga kellyi is a plural-brooded species, several generations occurring during the season. At least two and probably three generations went through to maturity as parasites of *D. longipennis* from early May to the middle of July.

The grasshoppers will die from the effects of the parasitism while in the act of feeding, and thus they are found hanging to a grass stem, the mandibles firmly attached, in their last dying grasp. The dead grasshoppers lying on the ground may be full of crawling maggots still feeding or endeavoring to issue from their host to enter the soil. When the maggots have emerged from the host only the shell of the grasshopper remains.

Methods of larviposition much similar to those noted by the writer have been recorded by Kunkel d'Herculais on *Sarcophaga clathrata* Meig. in Algiers during 1893–1905. Apparently the foregoing writer had only one species of Sarcophaga involved, as was true in the case of the writer during the present studies.

Second in importance as a controlling factor of *D. longipennis* was the preying upon the nymphs by the sphecid wasps *Priononyx atrata* Lep.

These wasps were always present in large numbers among the hoppers. Being very diligent workers, apparently working from sunrise to sunset during favorable weather conditions, the numbers of the grasshoppers were greatly depleted from their efforts. During the observations of the writer, however, only nymphs were noted to be attacked.

In nearly every instance the single nymph placed in each nest is stung before the excavation is undertaken, but occasionally the burrow will be completed before this is done. However, the female wasps frequently sting several nymphs during the period of constructing a single nest, and in one instance, observed by the writer, as many as five were stung by a single female while excavating an individual burrow. In this case it was the last nymph stung which was drawn into the burrow. The nest finished, the Priononyx flew away, leaving the other four victims lying upon the prairie in a comatose condition. The nymphs once stung by Priononyx seldom, if ever, regain consciousness. This habit, naturally, increases the efficiency of this species.

Usually the hopper is stung in the abdomen, but stinging in the venter of the head regions is common. The wasp, approaching the victim unawares, generally seizes and stings it so quickly that the grasshopper has little opportunity to offer any effective resistance. When a nymph is aware of the presence of a Priononyx it will suddenly assume the very characteristic protective attitude of defense.

Crouching close to the ground, it will raise the posterior pair of legs above the abdomen in the shape of an inverted V, whereupon it will remain perfectly quiet until the wasp has apparently departed. Though the Priononyx will occasionally attack a nymph while in this protective attitude, a severe struggle generally ensues, with the grasshopper infrequently the victor.

A large number of the nymphs which have been stung by Priononyx and left upon the prairie while she is building the nest are in the meantime larviposited upon by *Sarcophaga kellyi.*

The nest is usually built in compact sand. Between railroad tracks and along the right of ways are also desirable nesting places. The excavation of the burrow is commenced by the female rapidly scratching away the surface with the anterior pair of legs. As the depth of the burrow increases the head is cooperatively brought into play with the workings of the anterior legs, when finally the excavation of the burrow is completed by the wasp bringing huge mouthfuls of the soil to the surface. The burrow is excavated almost vertically downward to a depth of $1\frac{1}{2}$ to 2 inches and about one-half inch in diameter. The bottom of the burrow is then excavated in a horizontal direction until a cavity is made sufficiently large conveniently to permit of a nymph being placed within it. In dragging the nymph to the burrow the wasp assumes a horizontal position astraddle the victim. Seizing the nymph with her mandibles at the base of the antennæ, she drags it venter down to the entrance of the burrow. Then facing the nymph, still holding it at the base of the antennæ, she backs into the burrow, dragging in the nymph head foremost behind her. Placing the nymph in the horizontal cavity at the base of the burrow, venter down, in a horizontal position, she deposits a single egg. This egg, white in color, elongate oval, and somewhat curved, is invariably attached to the tender membrane at the base of the posterior coxa.

The egg having been deposited, the wasp proceeds to the surface. Taking a position, back to the burrow, she rapidly scratches the excavated soil into the hole. From time to time she packs down the soil with her head, which she uses as a most efficient ramming instrument. The excavation filled, the wasp carries small sticks, stones, cinders, and the like—these often much heavier than the wasp herself—and places them over the burrow. The time elapsing from the moment the nest is started until its completion usually varies from 30 minutes to 1 hour.

Though it is virtually impossible for the human eye to locate a completed Priononyx nest, there is a bembecid wasp, *Megastizus unicinctus* Say, a secondary upon *Priononyx atrata*, which without the least difficulty locates the Priononyx nest with the greatest exactitude. After Prionoyx has completed a nest, a Megastizus will locate it, reexcavate the burrow, and proceed to destroy the egg deposited upon the nymph by the sphecid. This egg is apparently destroyed by the Megastizus crushing it between her mandibles. The Megastizus then deposits upon the nymph an egg of her own.

Megastizus is not particular about refilling the burrow, nor does she attempt to hide the location of it in any manner, as does the Prionoyx. Oftentimes Megastizus will leave the nest when the burrow is not more than half refilled with soil. Occasionally the Prionoyx will be driven from her nest by Megastizus while in the act of filling up her burrow. Neither Prionoyx nor her nest, however, were ever noted to be disturbed by Megastizus until after the prey had been placed in the burrow.

Megastizus never attempted to sting a grasshopper during the present observations, but preyed upon Prionoyx entirely, in the rôle of a secondary within the sphecid's nest. Being present in considerable numbers, it most certainly affected the efficiency of Prionoyx to a great extent.

ARTIFICIAL REMEDIES.

The most effective artificial means of exterminating the grasshoppers of this species was found in the use of the poisoned bran mash. This was made as follows: Thoroughly mix together in the dry state 25 pounds of wheat bran and 1 pound of Paris green. Into a separate receptacle containing 2 quarts of a cheap molasses or sirup add the juices and finely ground skin and pulp of three oranges or lemons. Dilute the molasses mixture in 2 gallons of water and add to the poisoned bran mixture. Thoroughly mix the two together, adding enough more water, if necessary, to bring all to a stiff dough. This amount of poisoned bait will treat from 5 to 10 acres.

The bait should be sown broadcast early in the morning, before sunrise, in strips 1 rod apart, over the area to be treated. The most satisfactory method of distributing the bait is to sow it from the rear end of a buggy.

In using the poisoned bait as above, with lemons as the fruit employed, tremendous numbers of the grasshoppers were exterminated. As many as 75 dead grasshoppers per square foot were frequently found, several days after the application, over large areas. The grasshoppers usually die from 6 to 80 hours after taking the poisoned bait into the system.

Coarse-flaked brans should be used in preference to the fine-flaked varieties. Only those brands of Paris green which are guaranteed to contain not less than 55 per cent of arsenic should be employed. Arsenate of lead should not be used in any form. There have existed some differences of opinion as to whether oranges or lemons make the bait more effective. As 75 per cent of the efficiency of the bait is attributed to the use of these citrous fruits, this point is naturally a very important one. The writer, in extensive experiments with different species of grasshoppers, has yet to note any material advantage or marked difference of efficiency in favor of either oranges or lemons.

The Criddle mixture, as commonly employed in grasshopper extermination, was not experimented with during the present investigation for lack of available material. But as nymphs of this species are voracious feeders on horse droppings and dried "cow chips" there seems little question but what this bait could be effectively used if the ingredients were readily available.

On account of the irregularity of the land in the infested area of this outbreak the use of a hopperdozer was not practicable.

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BULLETIN No. 294

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LESSONS ON COTTON FOR THE RURAL COMMON SCHOOLS.

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INTRODUCTION.

In the cotton States the importance of elementary agriculture as a school subject is very generally recognized, and it is now being taught to a greater or less extent in a large proportion of the rural schools. More and more it is becoming a part of the daily program of the schools.

It is hoped that these lessons, exercises, and references on the growing of cotton, based on economic production and properly supervised, may serve as a supplement to the organized school work in elementary agriculture, contributing in a very definite way elements that can be obtained by no other means.

The application of the lessons as outlined here will put the boy at actual farm problems where the expenditure of more or less money is necessary and where profitable incomes may be expected. Thus, through textbook instruction, laboratory exercises, correlations, and practical work in the growing of cotton on the home farm, this bulletin will aid in developing the real educational value of this study.

LESSON I.

Subject.—Varieties of cotton.

Topics for study.—Points of difference between the following prominent and typical varieties of cotton: Cook Improved, Cleveland Big Boll, Triumph, Truitt, Lone Star, Rowden, Foster, Snowflake, Jackson, Trice, Griffin, Express, Russell, Columbia, Durango, and Georgia Big Boll. How many of these varieties are grown in your school district? Which has proved most profitable? Compare one of these varieties with some local variety not found in the list.

Note.—This bulletin furnishes elementary lessons on cotton and is of interest to rural school teachers in the Southern States.

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Emphasize the desirability of communities restricting themselves to one kind of cotton. Place the above varieties under the following groups: (1) Big-boll group (see fig. 1); (2) long-staple group (see fig. 2); and (3) small-bolled early group (see fig. 3).

Exercises.—Have six or more pupils bring all the varieties of cotton mentioned in this lesson they can find at home or in the neighbor-

Fig. 1.—Triumph.

hood. These samples should be used in studying the shape of plant, size and shape of bolls, and relative earliness and colors of seed. Have the pupils report in writing the opinions of several farmers as to which varieties are thought to make the largest yields of lint. Before the pupils attempt to select the most desirable plants from which to select seed for the next year's crop, have them read the references. Then have the pupil bring from the home farm that plant which he thinks approaches nearest to his ideal cotton plant for use in the lesson on judging cotton.

References.[1]—Bureau of Plant Industry Bul. 163; Office of Experiment Stations Bul. 33, pp. 197–224 (these two bulletins are procurable

FIG. 2.—Durango.

only from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 25 cents and 60 cents, respectively); Farmers' Bul. 601, pp. 3–5; U. S. Dept. Agr. Yearbook 1902, pp. 365–389.

[1] The references in this bulletin are to publications of the U. S. Department of Agriculture unless otherwise specified.

LESSON II.

Subject.—The botany of cotton.

Topics for study.—This lesson should deal with significant points, such as the morphology and physiology of the plant, including the effect of temperature and moisture on germination and rate of growth, branching habits, cross-fertilization and its effect, the range of type within the variety, and the significant features of well-recognized varieties. Such points as these have a direct bearing upon the lessons

FIG. 3.—King.

of judging cotton, seed selection, time and methods of planting, and time and manner of thinning.

Cotton roots: Dig down around a cotton plant and see how near the surface the roots grow. Compare the root system of cotton with corn, and determine the effect of deep cultivation after the plant is several inches high.

Stems and branches: Study carefully the different types of branches, their function, and arrangement on the plant, as these are important means of distinguishing varieties and determining productiveness and earliness.

A blooming cotton plant:

Root: Fibrous or taprooted?

Stem: Shape of stem, color of bark, color of wood.

Leaves: Alternate or opposite? Shape. Number of lobes. Make drawing showing veins.

Calyx: Size, shape.

Corolla: Color, shape, size.

Petals: Number separate or coalescent.

Stamens and pistils: Number of each. Make drawings of stamens and pistils.

Exercises.—Bring a sufficient number of cotton stalks into the schoolroom, or better still, go with the class to a field of standing cotton. Make notes of your observations in answer to questions on Topics for Study.

References.—Bureau of Plant Industry Circ. 109, pp. 11–16; Bureau of Plant Industry Buls. 221, 222, 249; Textbooks on elementary agriculture; Office of Experiment Stations Bul. 33, pp. 67–80.

LESSON III.

Subject.—Judging cotton.

Topics for study.—Object of cotton judging. Meaning of expression cotton "runs out." Four reasons for depreciation in productiveness and quality. Crossing versus selection as a means of improving cotton. Simplest method of selection. Principal qualities desired in the plant.

Exercises.—With the use of the score card and directions for judging cotton given below, determine the best plant selected by the pupils.

DIRECTIONS FOR JUDGING COTTON.[1]

1. The Plant.

On the score card as suggested the ideal plant is given a rating of 25 points. In judging the exhibits in contests, cuts should be made more severe as the plant departs farther from the standard.

For plants departing only slightly from the variety standard as to size, a cut of 1 to 1½ points should be made. If this departure is very marked a cut of 3 points may be made.

For excessively long joints and poorly placed and developed branches cut a maximum of 2 to 5. For slight defects in these respects cut from 2½ to 3 points.

For a plant which develops a single central stem bearing numerous horizontal fruiting branches allow five points as the perfect score.

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[1] Adapted from directions published by the Georgia State College of Agriculture.

Score card for the cotton plant.

The cotton plant.	Score. Perfect.	Student's.	Corrected.
Plant, vigorous, stocky, 25 points:			
Size, medium to large as influenced by soil, location, season, and variety	5		
Form, symmetrical, spreading, conical, height, and spread according to soil, etc.	5		
Stalk, minimum amount of wood in proportion to fruit	5		
Branches, springing from base, strong, vigorous, in pairs short-jointed, inclined upward	5		
Head, well branched and filled, fruited uniformly	5		
Fruiting, 24 points:			
Bolls, large, abundant, uniformly developed, plump, sound, firm, well-rounded, apex obtuse, singly or in clusters	4		
Number of bolls, according to variety, soil, and season	4		
Bolls per plant, thin uplands, 10–20; fertile uplands, 20–25; "bottoms," 50–100; special selection, 100–500	4		
Bolls per pound of seed cotton, large, 40–60; medium, 60–75; small, 80–110	4		
Character of bolls, number of locks 3 to 5; kind of sepals; retention of cotton	4		
Opening of bolls, uniform including top crop, classify as good, medium, poor	4		
Yield—standard 1 bale per acre, 30 points:			
Seed cotton, estimated by average plant, distance of planting, per cent of stand, plants per acre; thin uplands, 10,000; fertile uplands, 6,500; "bottoms," 4,500; distance of plants $3\frac{1}{2}$ by $1\frac{1}{4}$ feet, $4\frac{1}{2}$ by $1\frac{1}{2}$ feet, $4\frac{1}{2}$ by 2 feet, respectively	12		
Per cent lint, not less than 30, standard 33 to 35	12		
Seeds, 30–50 per boll, large, plump, easily delinted, color, according to variety; germination not less than 95 per cent	6		
Quality and character of lint, 21 points:			
Strength, tensile strain good, even throughout length	5		
Length, common standards for upland, short $\frac{7}{8}$ to 1 inch, premium $1\frac{1}{16}$ to $1\frac{1}{8}$ inches; long staple, $1\frac{3}{16}$ inches and better	5		
Fineness, fibers soft, silky, and pliable, responsive to touch	5		
Uniformity, all fibers of equal length, strength, fineness	5		
Purity, color dead white; fiber free from stain, dirt, and trash	1		

No. of plant.................... Source....................................

Type..

Remarks on plant..

Date......................., 19..... Name of student..............................

When the head is full, on account of superabundance of long upright branches, cut a maximum of three points. As these faults are less pronounced, reduce the cuts until for slight defects on these accounts a minimum cut of one-half point should be given.

2. Prolificacy.

In considering the fruitfulness of a plant or set of plants the term prolificacy can be used only in a relative sense. The plant possessing the greatest number and best-formed bolls should be given a rating of 24, or perfect in this respect, while others should be cut more or less severely as the number of bolls they bear falls below that of the standard. The single or cluster arrangement of bolls should vary with the typical habit of the variety; some varieties are cluster bearers while others are noted for bearing bolls singly. Uniformity in which the bolls are arranged on any exhibit should be made the standard. Give an exhibit absolutely uniform in this respect 4 points. As others are more or less irregular in this respect cut from 1 to $1\frac{1}{2}$ points on the score card.

Next in importance to prolificacy or number of bolls is their size, shape, and manner of opening. Large bolls yield more cotton per boll than do small ones. There is also a difference in the average size of the bolls on different plants of any single variety. The preference should be given to the plants bearing the larger bolls, provided, of course, that the quality of lint is maintained and the increase in size fully compensates for the decrease in number.

The shape or form should be true to that peculiar to the particular variety shown. Uniformity in shape or form in plants and fruit shows good breeding and also suggests ability to transmit desirable qualities to the progeny. Consequently it is of value to the plant breeder. As the bolls are of different shapes cut from one-half to one point as the number departing greatly from the variety shape increases. Special attention should be given to malformed bolls.

The way in which the mature bolls open is of importance. The opening should be such as to make the cotton easy to pick, but at the same time it should not be such as to cause easy shedding of lint. For the best opening bolls give the plant a rating of 5 points. If the opening is only fair make a cut of from 1 to 1½.

3. Yield of Seed Cotton.

Yield of seed cotton, while depending on the qualities already discussed, that is, the right kind of a plant and a sufficiently large number of bolls of good size and shape, should have considerable weight in fixing the value of superior rating of any cotton exhibit.

After the exhibit has been rated as to prolificacy and size of bolls, select a fixed number, say 10 four-locked or five-locked bolls already opened, pick the seed cotton from these bolls, determine the yield from these bolls, and then from this average calculate the yield from the entire 10 plants constituting the exhibit. Give the best yielding lot a rating of 30 points. Then as others yield less and less give them a maximum accordingly.

After total yield has been rated attention must be given to the percentage of lint produced by the different lots of cotton to be judged. This is given a possible rating of 12 points, which should be assigned only to samples showing not less than 35 per cent of the lint to the cotton seed. For each and every 1 per cent below 33 the sample should be given a cut of 1 point. Thus if a sample should only show 25 per cent lint it should receive a cut of 10 points, which, deducted from the possible score of 12 points, indicating perfection, leaves only 2 points to the credit of the sample.

The percentage of lint should be determined by taking the contents of a few bolls from each sample, placing them in the sun, or, better, in a dry room, for a period sufficiently long to bring the samples to a uniform point of dryness; after which the lint should be removed from the seed by hand, then each carefully weighed and the percentages calculated.

4. Quality of Lint.

Quality of lint is assigned a possible rating of 21 points on the score card. These are divided as follows: Strength, 5 points; length, 5 points; fineness, 5 points; purity, 1 point; uniformity as to length, fineness, purity, and freedom from faulty fibers, 5 points. Of course, these scores are only intended to offer means or standards by which the different exhibits may be compared. Therefore, when there are points about which there seems to be uncertainty the most perfect sample can well be given the highest score obtainable for that point. Then the others should be rated as they approach the standard fixed by this better sample. Thus, for the longest lint give five points and the same for the finest; also, that showing the greatest degree of purity and also for the greater uniformity. Then, as other samples fall short in any one of all these respects cut accordingly.

Exercises.—Combing and mounting (fig. 4) samples of seeds from bolls of different varieties will be instructive to pupils.

References.—Bureau of Plant Industry Bul. 222; Farmers' Bul. 591; cotton score card published by the State agricultural college; State cotton growers' association, if there is one.

LESSON IV.

Subject.—Selecting seed.

Topics for study.—Qualities desired in the plant. Four defects of boll to be looked for in selecting seed for planting. In how many directions does the cotton selected for judging purposes need improvement? Discuss how these improvements may be brought about. What constitutes good seed for planting? Where to obtain the best possible seed. How to gather seed for planting. Methods of separating large and small or heavy and light seed. Growing improved varieties, advantages, money value.

Exercises.—Let the pupils pick the cotton from 100 plants of poorest or least productive ones and weigh. From this weight determine how many plants of this type would be required to give a yield of 1,500 pounds of seed cotton or one bale of 500 pounds of lint. Then have the pupils pick the cotton from 100 of the best plants found in some cotton patch. Determine the number of bolls they contain, the average number per plant, the number required to give 500 pounds of lint, the number of plants required to produce this yield.

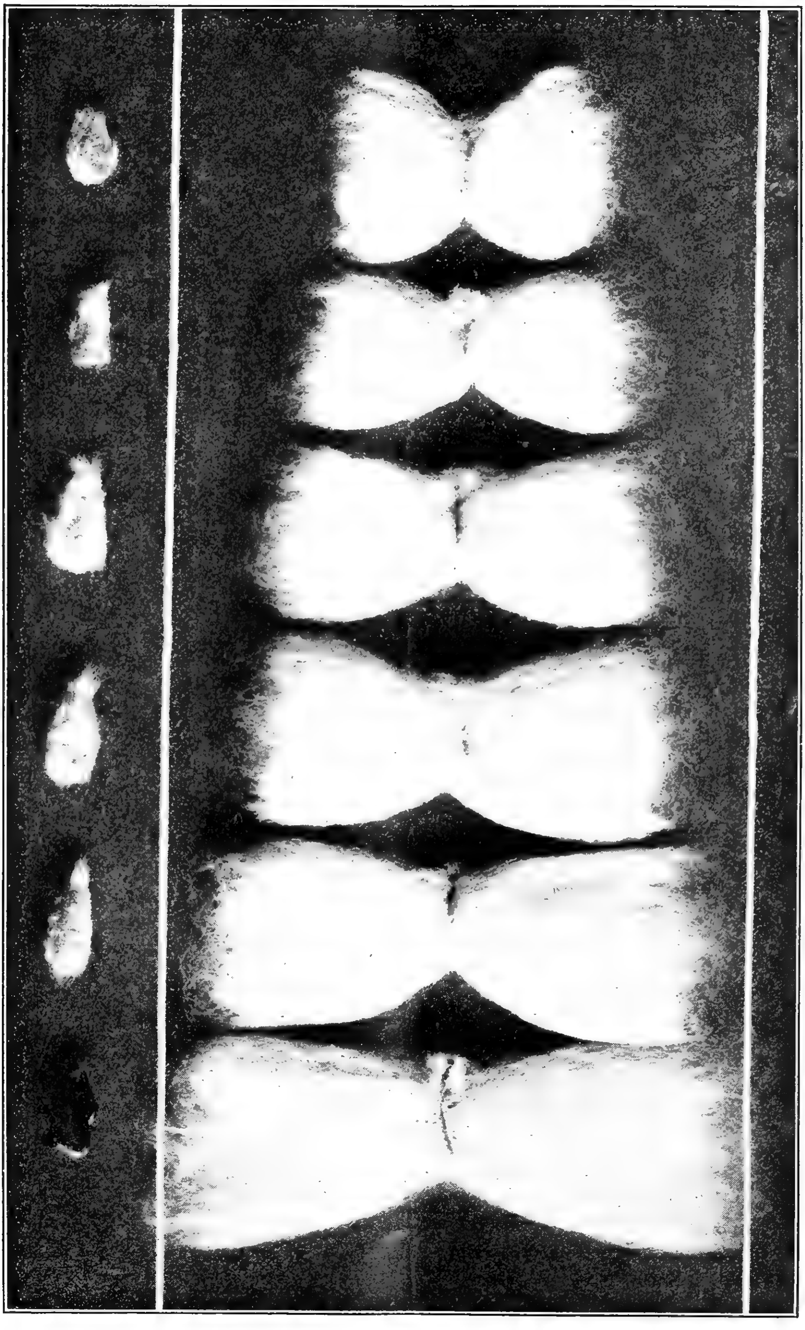

FIG. 4.—Varieties in order from top: Blackseed, Durango, Lone Star, Trice, King, and Half-and-half.

References.—Bureau of Plant Industry Cir. 66; Farmers' Bul. 501; Office of Experiment Stations Bul. 33, pp. 211, 212. Write to your State college of agriculture for literature on selecting seed for planting.

LESSON V.

Subject.—Place of cotton in crop rotation.

Topics for study.—(1) Reasons for rotation: (*a*) Different crops make different requirements of the soil; (*b*) root systems differ; (*c*) crops should be selected to suit varying seasonal conditions; (*d*) the culture of one crop prepares for a succeeding crop of a particular kind; (*e*) distribution of labor. (2) Cotton in systems of rotation. How would you make a crop of cotton regardless of the boll weevil?

Exercises.—Draw plans of the home farm, showing fields, and write in each field the crops in the order in which they were grown during the last five years. Write to the State agricultural college for (*a*) a system of crop rotation in cotton farming and for (*b*) a system of rotation in live-stock farming, which will help to create extensive home markets for roughage and leguminous crops and at the same time add to the fertility of the soil.

References.—Farmers' Buls. 326, p. 21; 364, pp. 8, 9; Office of Experiment Stations Bul. 33, p. 260.

LESSON VI.

Subject.—Preparation of the seed bed.

Topics for study.—It is good practice to plow any soils except the sandiest in the fall, provided some winter-growing crop, such as the small grains, or clovers, or vetches, are sown.

Kinds and conditions of soil necessary. Time of plowing. Methods of plowing or breaking. Depth of plowing. When should cover crops be turned under for cotton? Characteristics of a good seed bed.

Exercises.—Show the effect of plowing under cloddy soil, or a large cover crop, on the rise of capillary water; also the effect of disking a cover crop, or heavy coating of manure into the surface soil before turning under. Use four lamp chimneys, numbered 1, 2, 3, and 4. Fill all to a depth of 5 inches with a sandy soil. Finish filling No 1, using good loam soil. On top of the sand in No. 2 put 1 inch of wheat or oat chaff well packed down. In No. 3 put 2 inches of fine clods. Finish filling Nos. 2 and 3 with loam soil. Complete the filling of No. 4 by using a mixture of loam and the same amount of chaff used in No. 2. Set all chimneys in about 1 inch of water. Observe and explain results.

References.—Textbooks on elementary agriculture; bulletins published by the State agricultural college; Office of Experiment Stations Bul. 33, pp. 258–260.

LESSON VII.

Subject.—Fertilizers and how to apply them.

Topics for study.—What are the indispensable requirements for a good cotton yield? What is one of the surest fertilizers for producing a large cotton crop? Why? What element of plant food is needed most by the soils for profitable cotton production in your district? What necessary elements of plant food do commercial fertilizers supply? When are such fertilizers likely to be profitable and how should they be applied? Show the relation between profitable cotton production and the use of commercial fertilizers and legumes in different kinds of soils. Name the steps necessary in building up the soil permanently on a run-down cotton farm in your district.

Exercises.—If nitrogen is worth 16 cents per pound, available phosphoric acid 4 cents, and potash 4 cents, figure the value of the plant food in a ton of commercial fertilizer of the following composition: (1) Phosphoric acid 10 per cent, nitrogen 2 per cent, potash 2 per cent (10:2:2); (2) nitrogen 3 per cent, phosphoric acid 10 per cent, potash 3 per cent (3:10:3). What percentages of phosphoric acid, nitrogen, and potash are contained in a ton of fertilizer consisting of 900 pounds of acid phosphate, 800 pounds of cottonseed meal, and 300 pounds of kainit?

References.—Farmers' Buls. 44, 48, 326; Farm Arithmetic; Office of Experiment Stations Bul. 33, pp. 169–196.

LESSON VIII.

Subject.—When and how to plant cotton.

Topics for study.—At what time do the best farmers in your school district plant their cotton? Why should farmers wish to plant cotton as early as it is safe from frost? Is there any advantage in late planting in weevil-infested districts? There is no warrant in fact for the idea that only the earliest and most inferior of cotton can be grown under weevil conditions. See references on the importance of community action as to season of planting. The weevil invasion should lead to a better appreciation of the importance of growing improved varieties. Why? Close spacing, use and value in crop increase. Show reasons for and against flat planting and planting in beds. Which is frequently the practice in semiarid sections? Amount of seed per acre. How far are the rows spaced apart? Time and purpose of "chopping"? Show the relation between time of chopping and the branching habits of the plants and that delayed thinning may result in suppressing the vegetative branches and so increasing yield of cotton. What is the secret of a prize-winning cotton crop?

Exercises.—If each cotton seed planted 4 feet by 12 inches apart developed into a mature plant, how many seed would be needed to plant an acre of ground? How many pounds would that require for the different varieties? Source of cotton seed? How many pounds of cotton seed do the best farms in your district raise on an acre? How many bales of cotton do the best farms in your district raise on an acre? Show how the production per acre may be increased and the fertility of the soil maintained.

References.—U. S. Dept. Agr. Yearbook Sep. 579; Farmers' Buls. 36; 48; 364; 501, pp. 11–13, 21; 510, pp. 13, 14; 601, pp. 3, 4, 6, 7; Bureau of Plant Industry Circ. 1130; Office of Experiment Stations Bul. 33, p. 261.

LESSON IX.

Subject.—The cultivation of cotton.

Topics for study.—Stages at which a weeder or harrow is needed in the cultivation of cotton. Importance of first tillage. Under what special conditions may the turnplow be used for "barring off" cotton? Shallow cultivation. Proper depth of cultivation. Frequency of renewal. Advantages of closer spacing. What is best to sow in cotton along in August in order to make winter pasturage? What can be sowed at the last "plowing" of cotton that will serve as a winter cover to the land and furnish humus-forming material to be turned under the following spring? Discuss the importance of such a practice.

Exercises.—The effect of frequent shallow cultivation to maintain soil moisture may be shown by filling two cans or flower pots with rich soil and planting cotton. When the plants are 2 inches high cover the soil in one pot with a layer of coarse sand or granular dry soil to a depth of 1 inch. Place in a warm place and observe which plants first show the need of water.

References.—A New System of Cotton Culture and Its Application is the title of Farmers' Bul. 601. Practice of cultivation on a profitable cotton farm may be found in Farmers' Bul. 364, pp. 13, 14. Bureau of Plant Industry Circ. 1130. Office of Experiment Stations Bul. 33, p. 261. Nearly all the cotton States have one or more bulletins on this subject. These should always be procured from the State agricultural college and studied in class.

LESSON X.

Subject.—Insect and other enemies of cotton.

Topics for study.—The bollworm. The Mexican cotton-boll weevil. The cotton caterpillar. The cotton red spider. The nematode worm. The cowpea-pod weevil.

Exercises.—Find out from the farmers in the district the extent to which cotton is injured by the above insects. The teacher and pupils should study the features of the life history and of the seasonal history of the weevil that are of cardinal importance in control. If possible, have the pupils collect and preserve for the school exhibit local cotton insect pests.

References.—Farmers' Buls. 500, 501, 512, 606; Office of Experiment Stations Bul. 33, pp. 317–342.

LESSON XI.

Subject.—Cotton diseases.

Topics for study.—Cotton wilt. Cotton root rot. The control of root rot by crop rotation. Boll rot or anthracnose. Cotton rust. What should be said in reply to the question, "Do you know of any method of cultivation or any fertilizer that will prevent blight in cotton?"

Exercises.—Have the pupils gather data at home concerning the extent to which cotton is affected by the above diseases. If possible, have the pupils collect and preserve for the school exhibit local cotton diseases.

References.—Farmers' Buls. 555, 586, 625; Bureau of Plant Industry Circ. 92; Office of Experiment Stations Bul. 33, pp. 279–314. Nearly all the State agricultural colleges in the cotton States have one or more bulletins or circulars on this subject. These should always be procured and studied in the class.

LESSON XII.

Subject.—Harvesting and marketing cotton.

Topics for study.—The three chief elements to satisfy market conditions are: (1) A definite and well-established standard, (2) reliable and regular quotations based thereon, and (3) adequate storage facilities to protect cotton against the weather and country damage, and which at the same time places the cotton in position for the issuance of warehouse receipts that may be used for obtaining loans at low rates of interest. Time for harvesting. Gathering of the crop. Separation of fiber and seed. Baling of the cotton. The nine United States official cotton standards for grades in more or less general use. How is the grade of a sample of cotton determined? Reasons for protecting baled cotton from the weather.

Exercises.—Through your pupils and especially those in a cotton contest collect data for record blank shown on pp. 14 and 15.

References.—Department Bul. 62; Farmers' Buls. 302, 364, 591; Office of Experiment Stations Bul. 33, pp. 351–360, 381–384; U. S. Dept. Agr., Office of Markets and Rural Organization, S. R. A. 1.

LESSON XIII.

Subject.—Cotton seed.

Topics for study.—Cottonseed products in the feeding of farm animals; as a human food; as a fertilizer.

Exercises.—With the assistance of reference books such as Henry's Feeds and Feeding work out with the pupils a balanced ration which includes cottonseed meal for a dairy cow, a 1,000-pound steer, and a working mule. Also prepare fertilizer formulas, which will include cottonseed meal for the common truck crops and cereals as well as for cotton.

References.—Farmers' Buls. 22, 36, 170, 346, 410; Office of Experiment Stations Bul. 33, pp. 385–421.

LESSON XIV.

Subject.—Cotton and its products.

Topics for study.—Agricultural products of cotton. Manufactured products of cotton. By-products of cotton.

Exercises.—Which removes the most plant foods from the soil—cotton that yields 1,000 pounds of seed cotton per acre or corn that yields 25 bushels to the acre, the stalks and leaves left on the land in both cases? In comparative valuations of feeding stuffs to what extent in per cent does cottonseed meal exceed corn meal? In one ton of cotton seed how many pounds are there of hulls, meal, and oil?

References.—Farmers' Buls. 36, 286; Office of Experiment Stations Bul. 33, pp. 365–380.

EXHIBITS, REWARDS, AND ORGANIZATION FOR CLUBS.

Since the rural schools have begun to teach agriculture a wide and useful field for school exhibits has come into existence. Many teachers are using exhibits as the best means of calling the attention of their respective communities to the work that is being done in agriculture. It is well to hold an exhibit in the schoolhouse at the close of the contests and invite parents and others interested in school work to attend. Before an exhibit should be allowed to enter a contest or school credit given for a home project in cotton, a report similar to that given below should be kept and presented in good condition with the exhibit.

For information and suggestions on rewards or prizes as well as organization of clubs write your State agricultural college.

Record blank for club project in cotton.

CROP.

Season.......... Class.................. Variety........ Plants per acre.......
Character of soil........................ Crop for 5 years past......................

SOIL PREPARATION.

Date of plowing........................	Dates of cultivation......................
Implement used........................	Implements used........................
Depth plowed........................	Cost of preparing seed bed................
Cost of plowing........................	Condition of land when seeded..........

CROP SEEDING AND CULTIVATION.

Variety of cotton planted................	Amount of fertilizer per acre........
Date of planting........................	Cost of fertilizer........................
Cost of seed and seeding..................	Dates of cultivation......................
Per cent of stand........................	Implements used........................
Distance between rows..................	Cost of cultivation........................
Distance between hills..................	Kind of fertilizer........................
....	....

HARVEST AND YIELD.

Date of harvest........................ Yield in seed cotton......................
Days from seeding to harvest........... Cost of harvest............................
Remarks: ....
....
....
Approved: ....Teacher.
.................................Student. Age.......................................
Post office............................ ....School.
County.................................

Estimate the rental of your land at $5 per acre and your time at 10 cents per hour. Count all commercial fertilizers at actual cost, and homemade manures at $2 for a 2-horse load of about 50 bushels, and $1 for a 1-horse load of 25 or 30 bushels.

EXPENSES.

Rent of land...$......
Preparation of seed bed:
—— hours of horse labor, at 5 cents an hour for each horse....... ......
—— boys' labor, at 10 cents an hour for each ....
Cost of seed... ......
Cost of planting, boy's own labor —— hours, at 10 cents per hour ....
Cost of manure... ......
Cost of fertilizer, —— pounds, at $—— per ton................. ......
Cost of cultivation:
—— hours of horse labor, at 5 cents an hour, each horse.......... ......
—— hours of boys' labor, at 10 cents an hour.................... ......
Cost of gathering:
—— hours of boys' labor, at 10 cents an hour for each............ ......
Cost of ginning, baling, and marketing........................ ......

Total cost..$......

RECEIPTS.

Total value of lint, —— pounds, at ——...........................$......
Total value of cotton seed, —— pounds, at ....

Total receipts.. ......
Net profit.. ......

We, the committee, hereby certify that we have measured the cotton of ——— of ——— on this ——— day of ——— 19 , and that the following statements are correct: Length of plat, —— yards, —— feet; width of plat, —— yards, —— feet; area of plat, —— acres. The amount of cotton obtained, —— pounds, in the measured plat.

——— ———
——— ———
——— ———

SUGGESTIVE CORRELATIONS.

Reading and spelling.—The Farmers' Bulletins, the bulletins and circulars of the State college of agriculture, and the books that are consulted in connection with the study of the various questions raised while studying the subject of cotton will all give reading material of the best kind. Magazine articles and articles in the farm papers should be used freely for reading and discussion.

List and assign new words related to the cotton industry for spelling exercises.

Language lessons.—Written reports of field observations. Compositions on selection of seed in the field. A careful study of these compositions should be made to the end that the pupils may grow in power to express their ideas truthfully, systematically, adequately, and interestingly. Write letters ordering seed catalogues and asking for the quotation of prices on cotton. In these letters study for correct form, good composition, and for courtesy in expression.

Drawing.—Make drawings of ideal and faulty specimens of common varieties of cotton grown in the district. Collect, name, and make drawings of common weed and insect pests of cotton. Pupils should be encouraged to illustrate their descriptions by offhand sketches on the blackboard. Make drawings of the important parts of machinery used in cotton culture. In this connection emphasize the learning of the names and uses of implements and their parts.

History.—Study the history of the varieties of cotton common to the community as to their origin, time, and circumstances of their introduction and the success with which they have been grown. Special attention should be given to the development of the cotton gin and its relation to the cotton industry. The history of cotton in India, Egypt, Persia, the West Indies, and Brazil should be studied carefully. Study the history of weeds, insects, and fungous diseases of cotton as to origin, introduction, spread, damage done, and methods of combating.

Geography.—Study the commerce of cotton from (1) India to the Mediterranean countries; (2) Mediterranean countries to western Europe; (3) America to western Europe. Prepare maps showing lines of commerce and locate the principal receiving and distributing points for each agricultural product bought and sold. Study the trade that results from the exchange of agricultural products between your State and other States and countries; compare the exports and imports as to quantity, value, and character.

Arithmetic.—The business of the farm offers the best possible material for arithmetic study. Develop exercises on the cost of producing one bale of cotton per acre under different methods of farm practice. Problems involving the annual reports of club members should be developed. All business forms used locally, such as receipts, bills, freight bills for fertilizers, etc., should be studied in school.

"Correlating Agriculture with the Public School Subjects in the Southern States" is the title of Department Bulletin 132, published by the United States Department of Agriculture.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 295

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER October 28, 1915

THE ZIMMERMAN PINE MOTH.[1]

By JOSEF BRUNNER, *Assistant in Forest Entomology, Forest Insect Investigations.*

CONTENTS.

INTRODUCTION.

One of the insects of the order Lepidoptera very destructive to coniferous trees, and especially to yellow pine (*Pinus ponderosa*) in various sections of the West and, according to Zimmerman, Grote, and Kellicott, to white pine (*Pinus strobus*), Canadian or red pine (*P. resinosa*), Austrian pine (*P. austriaca*), Scotch pine (*P. sylvestris*), Swiss pine (*P. cembra*), and other pines in the East, is the Zimmerman pine moth (*Pinipestis zimmermani* Grote[2]). Aside from being largely the cause of "spike-top" (Pl. I) in mature timber, it spike-tops, stunts, and kills outright innumerable trees of the so-called "second growth." The timber of at least one area, thus far discovered, has been brought into such ill repute that carpenters and builders refuse to use it for anything in which "never-ending shrinkage" is objectionable.

Having noted during several seasons the severe injuries inflicted by the larvæ of this insect, the writer, at the suggestion of Dr. A. D. Hopkins, undertook, during the autumn of 1912, a systematic study of its seasonal history and habits, the recorded information on this insect being inadequate. This study was conducted during 1913–14 in conjunction with other work on insects which affect reproduction and

[1] *Pinipestis zimmermani* Grote.

[2] Identification by August Busck.

NOTE.—This bulletin is of special interest to manufacturers and users of pine lumber from the Western States.

4249°—Bull. 295—15

the development of forest trees, with a view of discovering possible methods of elimination or at least amelioration of its ravages.

Definite details were gathered only in certain areas within the States of Montana and Idaho, but correspondence with the other forest insect field stations in the West, together with larvæ collected and forwarded from those stations, proves that this moth occurs almost everywhere in the West. Considering that Packard records its occurrences in New York and Pennsylvania, it is evident that this insect is probably distributed over most of the United States. Its habits and the result of its larval work also apparently do not vary materially anywhere in its range. These facts lead to the conclusion that the remedy outlined below should be as effective in other regions as in the West.

DESCRIPTION OF THE INSECT.

THE ADULT.

The length of the moth (Pl. II, fig. 1) is about one-half inch. There is no appreciable difference in size and coloration between the two sexes although the general color of individual specimens varies from a light gray to a reddish gray and the body of specimens having the latter hue on head and thorax is usually dark gray. The underside of the entire insect is of a uniform gray color.

The wing expanse is from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches. The fore wings are shaded reddish on the basal and terminal fields, the median space, divided from the latter by W-shaped lines, being blackish and gray, these two colors being again divided by a small white bar on a brownish field.

The hind wings are pale yellowish white, the color becoming deeper toward the terminal fringe, which is paler than that of the fore wings, on which it frequently shades to a dark gray. These characters agree fairly well with Grote's description.

THE LARVA.

When full grown the caterpillar (Pl. II, fig. 2) is about three-fourths of an inch in length. The head is chestnut brown, the mandibles black. The body is naked, with a series of dots, darker than the skin, from each of which issues a single bristle. It has three pairs of thoracic legs, four pairs of abdominal prolegs, and a pair of anal claspers. The body varies greatly in color, which ranges from a dirty white, through reddish yellow, to a vivid green. The larva found in yellow pine is almost invariably gray-brown, resembling the color of the bark of the host tree, while those in Douglas fir are of such a vivid green color that it seems almost incredible that they should be representatives of the same species which infests pine. Rearing them to the adult stage, however, always dispels any doubt in this regard.

Variations in color, about which Grote and Kellicott differ, are evidently merely a matter of host differences.

THE PUPA.

Freshly formed chrysalids are of a light brown color, which changes to blackish brown as the moth within develops toward maturity.

The chrysalis is cylindrical, about three-fourths of an inch long, rather slender, and without spines on the segments. This last character makes it readily distinguishable from a sesiid pupa, which is frequently found under somewhat similar conditions.

SEASONAL HISTORY AND HABITS.

While adults emerge and mate from about May 1 to September 15, the maximum flight of the moths occurs during the month of July. They appear to be rather long lived, many 2-weeks-old specimens reared in the laboratory being as ready to take wing when disturbed as when they had just burst the bonds of the chrysalis. No other species of moths reared in captivity the larvæ of which feed on internal tree tissues were observed to live more than 10 days after emergence under similar conditions. The longevity of the Zimmerman moths evidently extends the period of mating beyond the general flight, and consequently fertilized eggs are deposited during any of the milder months.

Larvæ of all sizes, except the most minute in winter, may be found at any time of the year.

Though frequently but a single larva is found in a wound, the writer is of the firm opinion that eggs are almost invariably deposited in clusters. In the many observations while the larva was less than three-eighths of an inch in length six or more of them were always found in one infested spot. From a specimen of yellow pine 6 inches in length and but 1 inch in diameter showing old work, which was placed in a breeding cage during the middle of December, a month and a half after heavy frost had ended all outdoor insect activity, seven larvæ emerged early in January from eggs which had evidently been deposited on this small specimen during the previous late autumn. (Pl. II, fig. 3.)

Again, it is often the case that a space a foot or more wide and several feet long on a tree trunk has the cambium literally honeycombed with the tunnels of numerous larvæ. In one such case the writer found 27 nearly mature Pinipestis larvæ at work.

In mature stands, in "spike-tops" in the making, and at the bases of new spikes, plural infestation is evidently the rule.

This conclusion is verified to some extent by the observations of Mr. W. D. Edmonston at the Forest Insect Field Stations at Ashland, Oreg., and later at Colorado Springs, Colo., and by quite a number of larvæ and valuable notes that he sent to the writer. These notes generally end with the statement: "Under bark in hardened pitch were found empty pupa cases," or "Empty chrysalids were found in the pitch masses."

Since no other pitch moth so seriously destructive to the trunks of mature or nearly mature trees leaves the entire pupa shell *within* the bark or the pitch which sheltered the immature insect, its identity is quite easily determined.

The eggs deposited in July appear to hatch within about two weeks. During the latter part of August the young larva manifests its presence in infested trees rather plainly by the mixture of coarse castings and brown bark dust which is thrown out through the entrance and other holes in the bark made by the larva. Unlike the larvæ of the sesiid pitch moths, the pine moth caterpillar does not work into the cambium and stay there. Quite often, if not always, after attaining nearly half its full growth, it leaves the place where it hatched and drills into the tree tissues again at a spot which presumably suits it better, not infrequently several feet away from the original spot. To this migratory habit probably must be attributed the frequent occurrence of but one larva in a wound, except in instances where the work of woodpeckers accounts for their isolation. This assumption seems to be supported by the fact that all such hermits when located are developed well toward maturity.

As the larva grows and the inactive season approaches, this promiscuous gnawing of holes in the bark ceases. In no case even where most of them remain where they first saw the light is migration resumed the following spring. In the spring each larva prepares for pupation in its own individual tunnel, though under the same space of infestation, by lining it with silky thread. Packard states [1] that "the worm in July spins a whitish, thin, papery cocoon in the mass of exuding pitch, which seems to act as a protection to both the larva and the chrysalis." This applies to the insect in the East. In the West the caterpillar of the pine pest restricts its weaving operations before pupating to the above-mentioned lining of the tunnel. Cocoons which answer Packard's description are frequently found in these tunnels, but they are of a parasite which will be referred to later.

On approaching maturity, about the middle of June, the larva grows sluggish and is found to be transformed into the chrysalis within a few hours. When the moth has attained full development, 29 days from the time the pupa was formed and a year after the egg was laid, it merely bursts the chrysalid skin, leaving the empty shell within the tunnel, and pushes its way out through the very thin pitch covering at the mouth of the tunnel. The period of pupation in captivity under very varying temperatures and during all seasons

[1] Packard, A. S., Insects Injurious to Forest and Shade Trees. 5th Rpt. U. S. Ent. Com., 955 p. (p. 731), 38 pl., 306 fig., 1886–1890.

within a period of two years has in all cases proved to be exactly 29 days.

Eggs laid the previous autumn hatch in early spring and develop into adults during August and September of the same year, while eggs deposited during May evidently develop into adults early the following spring.

RELATION TO OTHER INSECTS.

In the northern Rocky Mountain region *Pissodes schwarzi* Hopk.[1] is a common associate of the pine moth in yellow pine, if the trees are attacked near the base. It appears that there the moth takes as frequent advantage of the work of the beetle as the beetle does of the moth's. The result of infestation by either of them is exactly alike, although the latter's attack is by no means restricted to the base of trees, while the work of the beetle is rarely found more than 2 or 3 feet above ground.

Sesia brunneri Busck,[2] wherever it exists (at present known in Montana and southern Idaho), is frequently associated with Pinipestis in yellow and lodgepole pine. While the attack by the Sesia in lodgepole pine appears to invite and to be the cause of subsequent infestation by the Pinipestis, the former frequently takes advantage of the work of the latter in yellow pine greatly to augment its own numbers. When this sesiid moth attacks a tree primarily it invariably deposits but one egg at a spot; but when it infests the pine moth's work in yellow pine it seems always to deposit quite a number of eggs. The writer has taken as many as six nearly mature Sesia larvæ from a single space surrounding a spot previously infested by the pine moth. The space infested by the latter is always killed and subsequent infestation can only occur at the border of such a spot. As the Sesia larva works parallel with the grain of the wood, its infestation of Pinipestis work becomes evident on the surface of the surrounding fresh bark by regular pitch masses of the size of a silver dollar instead of the general pitchiness which characterizes pine pest infestation, owing to the numerous holes it makes in the bark.

If the pine moth reinfests such a Sesia-infested space, its larvæ, feeding on the strictly fresh cambium surrounding it, usually stop the necessary flow of sap to the space occupied by the Sesia and the latter is starved to death on this account. To comprehend how this is possible, it must be understood that the sesiid larva is not able to move around at will on the surface of the bark, that it is apparently unwilling, if not unable, to cross spaces already sapped by other insects, and that it requires two years to complete its life cycle.

Two small moths of the genus Laspeyresia,[3] one in yellow pine and one in Douglas fir, frequently breed in the work of the pine moth in

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[1] Identified by A. D. Hopkins.

[2] Busck, August. Descriptions of new microlepidoptera of forest trees. *In* Proc. Ent. Soc. Washington, v. 16, no. 4, p. 143–150, pl. 7–8, 1914.

[3] Identified by August Busck.

considerable numbers. However, the relation seems to be of no economic importance.

In Montana and Idaho another species of Pinipestis, *P. cambiicola* Dyar,[1] is one of the most important factors in regard to the existence of *Pinipestis zimmermani* Grote. It infests during the latter part of June the cambium of the terminal branches of mature yellow pine, and many of these wounds are subsequently reinfested by the latter year after year. The work of this insect is almost invariably the primary cause of the knobby growth on branches in which the Zimmerman pine moth breeds undisturbed by woodpeckers or parasites, and this moth must therefore be regarded as a provider of brood trees for the more destructive *Pinipestis zimmermani*. (Pl. III.)

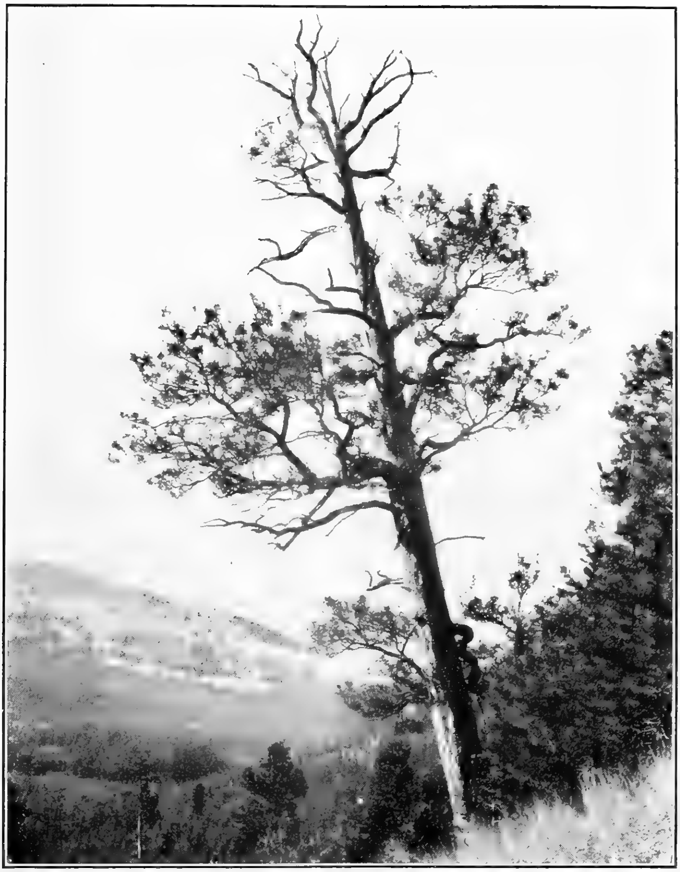
RELATION TO NATURAL ENEMIES.

In most sections of the Rocky Mountains the Rocky Mountain hairy woodpecker (*Dryobates villosus monticola*) is unquestionably the most efficient natural force in restraining the Zimmerman pine moth. Thousands of trees are each year regularly infested by the moth in comparatively small areas, and this bird as regularly destroys almost all of the larvae in all of them during early winter, so that, although hundreds of trees may be examined at a time, it is only on rare occasions that larvæ are found after December in wounds in the trunks of trees which had been infested during the previous summer. This woodpecker seems to have a decided preference for the caterpillar of the pine moth wherever the writer and the entomological rangers assigned to the Northern Rocky Mountain Field Station have had opportunities for observation. In the extreme southeastern part of Montana, and particularly that portion covered by the Northern Cheyenne Indian Reservation and by the Custer National Forest, the moth has apparently neither bird nor insect enemies. In all other localities this woodpecker is fully able to eliminate this insect as a serious factor in timber destruction. Especially will the work of the bird become effective when the habits of the moth are more generally understood and its "brood trees" are eliminated through use by man.

From reports from other field stations the writer concludes that from Idaho west toward the Pacific coast and in the southern Rocky Mountain region woodpeckers are of no consequence as a check upon this insect. But, considering that much confusion still exists concerning the identity of Pinipestis among the "pitch moths," this conclusion may prove erroneous when more thorough information is available.

The woodpecker never molests the caterpillars of the pine moth which live under "spike tops" and in knobby branches on certain

[1] Identified by H. G. Dyar.



REPEATED INJURY BY THE ZIMMERMAN PINE MOTH TO LARGE TREE, RESULTING IN "SPIKE-TOP." (ORIGINAL.)

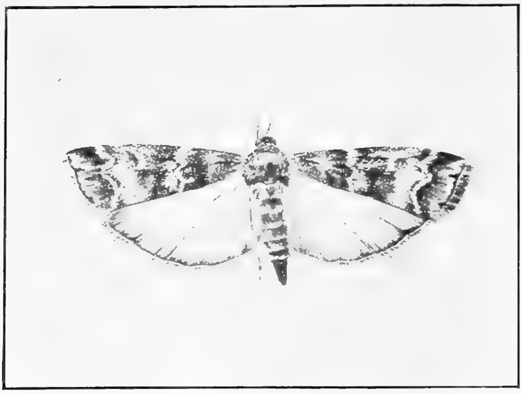


FIG. 1.—ADULT MOTH. SLIGHTLY ENLARGED. (ORIGINAL.)

FIG. 2.—LARVA. TWICE ENLARGED. (ORIGINAL.)

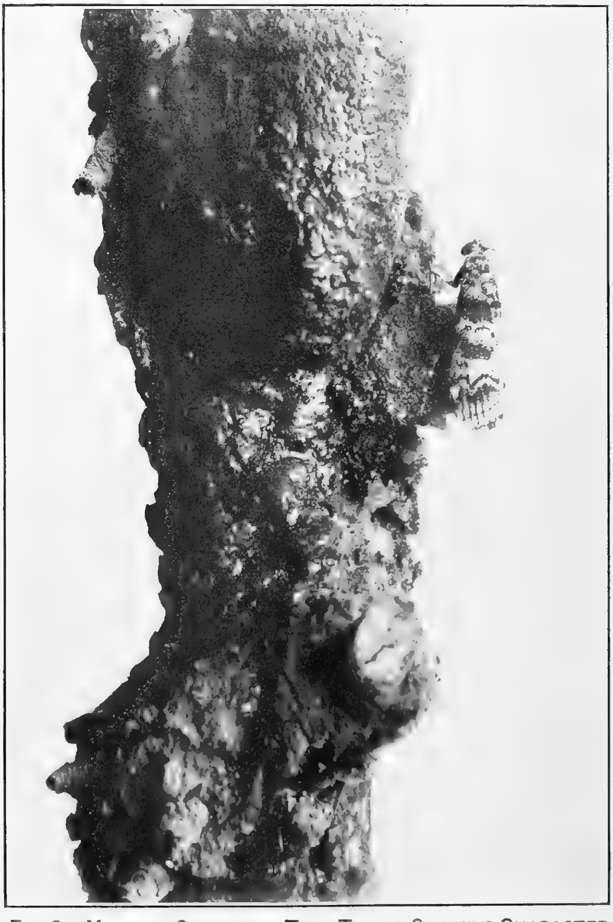
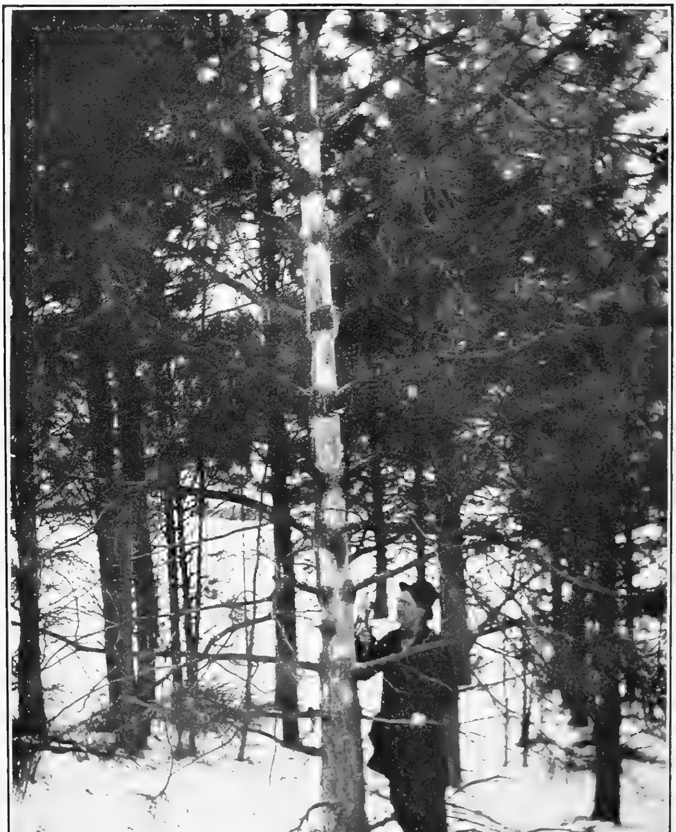


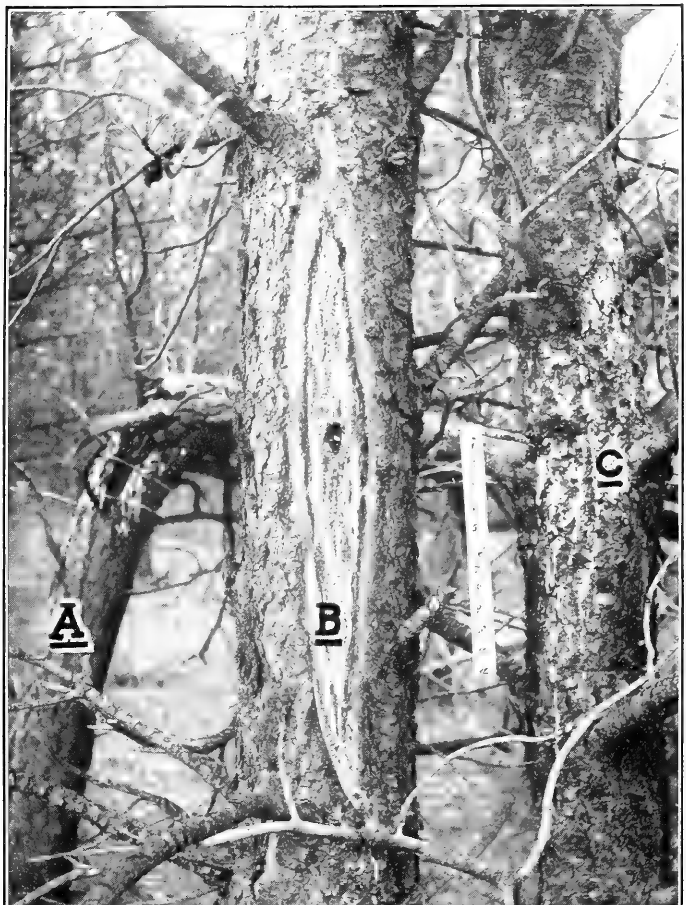
FIG. 3.—MOTH ON SECTION OF TREE TRUNK, SHOWING CHARACTER OF INJURY. SEVEN LARVÆ WERE FOUND IN THE BARK OF THIS SECTION IN DECEMBER. (ORIGINAL.)

THE ZIMMERMAN PINE MOTH (PINIPESTIS ZIMMERMANI) AND ITS WORK.

PINE SHOOT SHOWING PRIMARY INJURY BY PINIPESTIS CAMBIICOLA, AND INFESTATION, TWO YEARS LATER, BY THE ZIMMERMAN PINE MOTH. NATURAL SIZE. (ORIGINAL.)



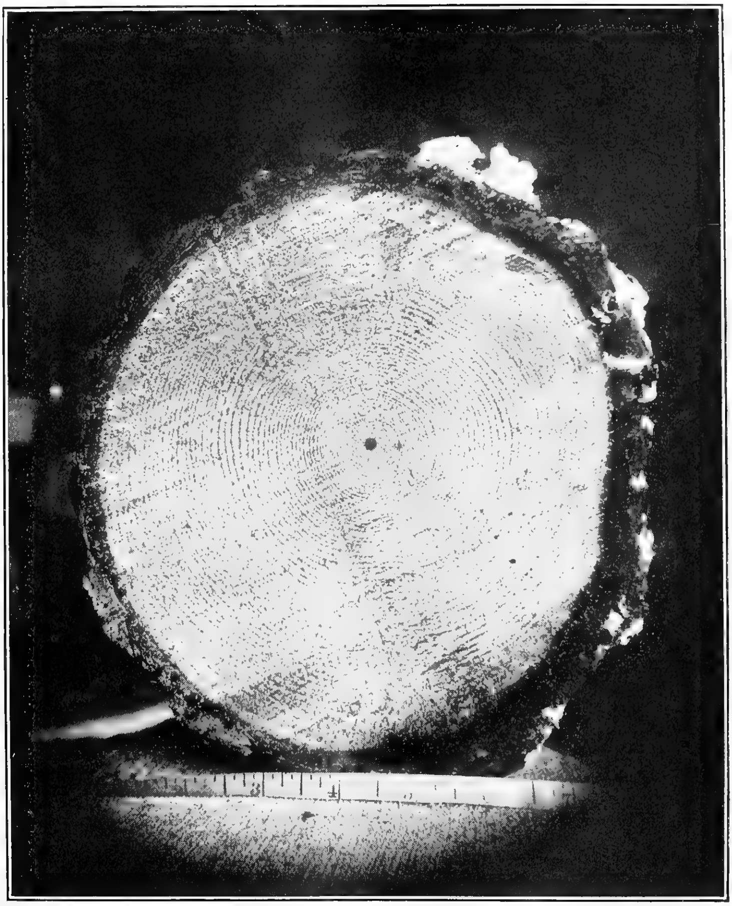
PINE TREE SHOWING RESULT OF REPEATED ATTACK BY THE ZIMMERMAN PINE MOTH, AND THE INJURY AGGRAVATED BY THE ROCKY MOUNTAIN HAIRY WOODPECKER IN ITS SEARCH FOR THE LARVA. (ORIGINAL.)



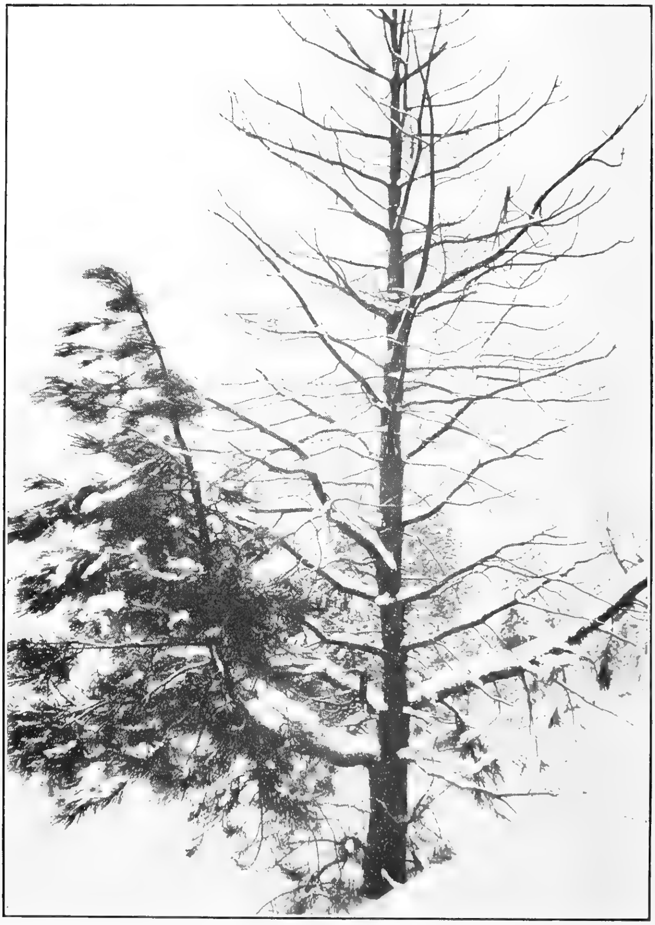
YELLOW PINE SHOWING CHARACTER OF INJURY BY THE ZIMMERMAN PINE MOTH.

A, Tree broken at injury; *B*, tree attacked by insect and insect removed by woodpeckers; *C*, tree girdled and killed by the insect. (Original.)

CROSS SECTION OF PINE SAPLING SHOWING EFFECT OF INJURY BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)

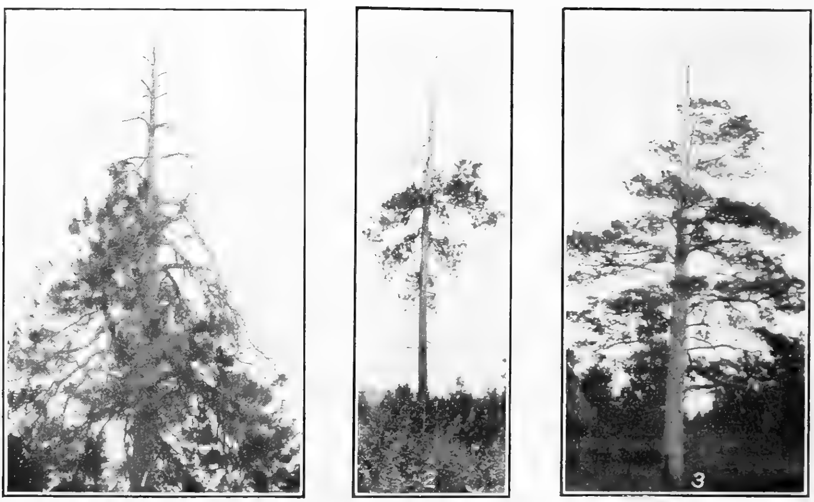


CROSS SECTION OF OLD, SLOWLY-GROWING YELLOW PINE SHOWING INFESTATION BY THE ZIMMERMAN PINE MOTH AND ITS INJURY IN BARK. (ORIGINAL.)



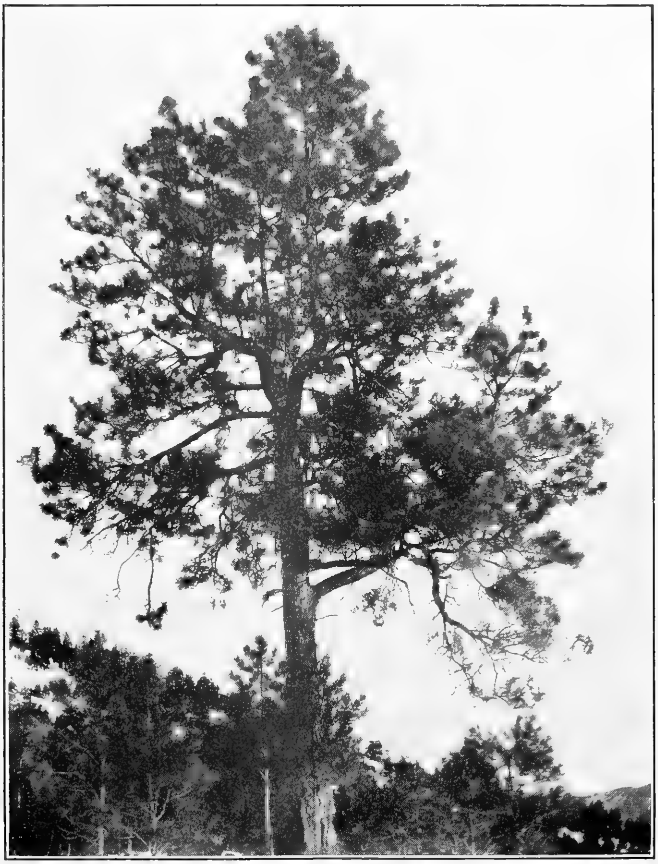
PINE TREE SHOWING EFFECT OF CONTINUOUS INJURY BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)

LONGITUDINAL SECTION OF YELLOW PINE SAPLING SHOWING RESULTING DAMAGE TO WOOD FROM ATTACK BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)



FIGS. 1, 2, 3.—TYPICAL YELLOW-PINE "BROOD TREES" OF THE ZIMMERMAN PINE MOTH.

The removal of such trees and the burning of the affected parts is the most effective measure for the control of this pest. (Original.)



OLD YELLOW-PINE TREE SHOWING RESULT OF INJURY TO TOP BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)

mature trees (see *Pinipestis cambiicola*, p. 6) and this is evidently the reason why its activities bear no permanent fruit. Considering also that the birds in hunting for the larvæ strip the trees of as much bark and cambium as the moth larvæ destroy in one generation, and that this operation is repeated each season, it is doubtful whether the woodpecker cure is not as bad as or even worse than the moth evil, when one considers that the brood trees are allowed to replenish the ranks of the insect year after year. (Pl. IV.)

The cocoon of a pimplinid of a new genus and new species [1] is frequently found in the tunnels of the pine moth in Montana and Idaho. In some localities this parasite kills as many as 80 per cent of the larvæ of the moth in second-growth trees. As the parasite cocoons are not molested by woodpeckers, a full quota of this fly emerges during the first warm days of each spring. While this parasite greatly aids in checking the increase of the moth from larvæ which infest second growth, it fails, as does the woodpecker, to pursue the caterpillars in the above-mentioned brood trees. Hence it is as much of a signal failure as is the bird.

Another, somewhat larger parasite (*Ichneumon* n. sp.[1]) is frequently found during winter in the chrysalis of the moth. The moth does not pass the winter in the pupal stage, and chrysalids found at that time always contain the parasitic fly, which, like the pimplinid, emerges during early spring. It is apparently less numerous than the latter and consequently of still less economic importance.

There seems to be justification for the conclusion that, without man taking a hand by eliminating the main propagating opportunities, no natural enemy of the moth will ever render it harmless. With human aid these agents will accomplish all that can be reasonably expected of them, i. e., the elimination of the ravages in rationally managed woodlands.

HABITAT AND HOST TREES.

Open, sunny stands of timber are those most affected by the Zimmerman pine moth. Slashings, on which reproduction has reached a height of 10 feet or more, having a scattered stand of mature trees, which were left standing to reseed the area or on account of being unfit for logs, invariably contain the greatest amount of pine-moth injury. It appears to be an absolute necessity to the insects' existence in a locality stocked with second growth, that the stand contain some of these specimens, which constitute brood trees for this insect. Where the mature timber has been cut clean over quite large areas, so that the chance for influx from without is remote, the insect does no damage, even though the ground may be stocked with an ideal

[1] Determined by S. A. Rohwer.

stand of second growth. Yellow pine, lodgepole pine, and Douglas fir are the tree species thus far noted to be subject to infestation by this insect in the West. Out of a hundred trees so infested about 80 per cent are yellow pine, 15 per cent lodgepole pine, and 5 per cent Douglas fir. Trees with a thick layer of fresh bark and cambium, as well as the more vigorous growers, are preferred for attack. All sizes, from but a few inches to several feet in diameter, are subject to infestation; but it is the mature trees which furnish the most favorable means of existence for this moth, while in the smaller ones, up to about a foot in diameter, it does the greater damage. (Pl. V.)

CHARACTER OF INJURY AND WORK OF LARVÆ.

The moth, as a rule, attacks mature trees from between 10 to 30 feet from the top down, and second growth from about breast high up to from 35 to 40 feet. Infestation nearer the top or base occurs only to a very limited extent.

As stated under "Seasonal history" (p. 4), fresh infestation is only indicated by the castings on the surface area of the attacked trees. If this area is very heavily infested, as in the case cited above, where the writer found 27 nearly mature larvæ in a space less than 5 feet in length by about 1 foot in width, there is at no time any other indication observable. The bark dries up without exuding pitch, as if scorched by extreme heat, and several years after the insect has vacated the bark drops off and the injury becomes manifest to the average passer-by. Usually, however, in such cases some larvæ leave the point originally infested and bury themselves higher up near a branch of the same tree. The pitch tube at the entrance of this tunnel invites close examination of the entire tree, whereupon the less conspicuous, yet heavy infestation is almost sure to be detected. (Pls. VI and VII.)

During the spring following infestation drops of pitch usually begin to ooze out of the tunnels in the bark and cover the surface of the average wound with a uniform, thin layer, somewhat similar in appearance to a liberal application of paint with a brush. The inner bark assumes a spongy appearance and gains in thickness, which tightens and even breaks the outer bark, together with the dried pitch covering it. The entire infested space finally presents a strikingly rough aspect which resembles the injury of no insect except *Pissodes schwarzi*, which produces a similar effect at the base of trees.

By repeated infestation at the border of the wound, in the course of years the tree is gradually girdled and the part above the collar dies and finally rots off at its base, provided the moth abandons the tree at this stage. But frequently infestation continues downward, on young trees usually until the lower branches, which by that time show a tendency to develop into tops, are reached and the trees killed, and on mature ones to a point where the thickness of the bark fails to suit the insect. (Pl. VIII.)

On wounds infested by a single larva a pitch tube, resembling that produced by sesiid pitch moths, is usually formed, presumably because one larva alone is not capable of cutting as near the surface as when several work together in one space. In the latter case the tunnels cross and recross continuously, and when a larva strikes the tunnel of another, which must happen frequently, it usually cuts to the surface in order to avoid the solidified pitch. To the presence of the larva so very near and even at the surface of the bark must be attributed its rather heavy parasitization in localities where its parasite exists, because larvæ living singly are very seldom parasitized.

EFFECT OF INFESTATION ON TREE GROWTH AND FOREST.

It is obvious that the killing of many trees in stands preferred by the moth results in too great a thinning out of the stand. This wastage of ground is further augmented by the permanent stunting of a still greater number of trees by the insect's work, because the space taken up by such scrubs would just as readily accommodate thrifty, well-formed trees.

Moreover, the wood from trees that have been infested by the moth is invariably so permeated with pitch that the lumber cut from such logs is either materially reduced in value or is rendered wholly unfit for commercial use. (Pl. IX.) From one part of southeastern Montana, where this moth is especially abundant and a large percentage of the trees are pitch soaked, the lumber is, for this reason, only used for sheds, etc., where shrinkage can be discounted; the users find it cheaper to have the better material shipped in than to pick it out of the local stuff and throw half of it away unless it is needed for the less particular purposes indicated. To the writer this practice at first seemed rather to indicate prejudice against the home product, because there is a large amount of first-grade lumber produced along with the bad. However, the pine moth is responsible for this condition, as was abundantly proved by examination of its injury in the district. The manner in which the moth's work "pitchifies" the wood is best seen in the well-known tops which have been infested by it. From these tops the bark has dropped off, but the surface of the wood has a roughened appearance and the tissues are literally saturated with pitch, while at the lower end, where the infestation ended and the wood was not pitchified in the process, the spike is rotted off from the tree. This insect's work alone accounts for the fact that the extreme top of a tree may be excessively pitchy, while the rest of the same tree is not.

REMEDY.

There is probably no other seriously injurious insect which can be eliminated with less expense and trouble than the Zimmerman pine moth, because practically everywhere, wherever its existence is causing real damage, the country is readily accessible, being either already logged over or adjacent to settled farming land.

In slashings the remedy consists in logging, thus removing the mature trees as soon as the area is reseeded, and in any other wood lot, where it shows its presence in the second growth, in merely using all "spike-topped," lightning-struck, and heavily branched mature trees for firewood or domestic purposes. These are the "brood trees" in the great majority of cases, and their disposal ends the trouble in the growing trees. The larva in these three types is found at the base of the spike, along the scar caused by the bolt, and in the knobby growths on the branches which are the result of primary injury by *Pinipestis cambiicola* (in the West) and probably other insects. The affected parts should be destroyed, the simplest way being to burn them before the arrival of spring. The judicious choosing of the right trees for firewood for home consumption alone would prevent on many farms further damage by this insect to the growing trees. In one wood lot east of Missoula, Mont., covering about 40 acres of a quarter-section farm, 25 per cent of the second growth had been infested annually for several seasons, and the cutting of only three overmature trees during 1913–14 for firewood ended the damage absolutely. One of them was a still infested spike-top and two were full of knobby branches, also infested. There are still about 80 overmature trees standing on that farm, but the three cut were evidently, as supposed before the cutting, the only "brood trees," and, as the woodpeckers had taken care of the infestation in second-growth trees, the elimination of the moth at that place was a natural result of the disposal of these trees. (Pls. X and XI.)

In a locality about 5 miles north of Missoula, Mont., where at least 3,000 second-growth trees are infested and reinfested annually, the writer is positive that the cutting of not more than 24 overmature "brood trees" in a stand of about 1,000 of the same age as these would effectively end the continuous depreciation. In other localities not so thoroughly examined, the proportion of work necessary to end the trouble appears to average about the same. Even in southeastern Montana, though the moth is not subject there either to woodpeckers or parasites, the insect damage could be greatly reduced, if not eliminated, by disposing of the "brood trees" by merely selecting them for fuel.

CONCLUSION.

It is evident that natural agencies have not succeeded in preventing, and will not be able in the future to prevent, serious damage by this moth unless man aids their efforts by disposing of such trees as have fulfilled their usefulness in the forest and wood lot, and which, instead of being an asset there, have become a menace. To end "spike topping" in mature stands, and to eliminate damage in growing timber, or at least reduce it to a negligible amount, it is necessary to remove (1) those trees which, below the spike, show branches with yellow needles (a certain indication of present infestation), (2) those which are struck by lightning and remain green, as the moth usually breeds in great numbers along the lightning scars, and (3) those which display knobby growths on branches, they being in many localities the most prolific source of replenishment of the moth.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 296

Contribution from the Bureau of Crop Estimates
LEON M. ESTABROOK, Chief

Washington, D. C. ▼ October 25, 1915

OUR FOREIGN TRADE IN FARM AND FOREST PRODUCTS.

Prepared under the direction of PERRY ELLIOTT, *Division of Crop Records*.

CONTENTS.

SUMMARY.

The foreign trade of the United States has increased more than tenfold during the last 64 years, the products interchanged with foreign countries being valued at 400 million dollars in 1851 and 4,259 million dollars in 1914. The exports of domestic merchandise were valued at 179 million dollars in 1851, of which 147 million dollars, or 82.1 per cent, were agricultural products; the exports of domestic merchandise increased to 2,330 million dollars in 1914, of which the agricultural value was 1,114 million dollars, or 47.8 per cent.

The imports of merchandise in 1851 were 211 million dollars, of which 61 million dollars, or 28.7 per cent, were agricultural products; this trade increased to a grand total of 1,894 million dollars in 1914, of which the agricultural portion was 924 million dollars, or

NOTE.—This bulletin is a summary of the leading features of the foreign trade of the United States in farm and forest products. It is intended for general circulation.

48.8 per cent. The foreign or reexports increased from 10 million dollars in 1851 to 35 million dollars in 1914. The reexports of agricultural products in 1851 were 5 million dollars, or 49.4 per cent, and in 1914 were 18 million dollars, or 50.8 per cent.

During the period 1851–1914 there has been a balance of trade in agricultural products in favor of the United States with the exception of 1864 and 1865; for those two years the balance against this country—that is, the excess of imports over exports—was 26 and 11 million dollars, respectively. The smallest balance in agricultural products in favor of this country was 27 million dollars in 1869 and the largest balance was 571 million dollars in 1901.

The exports of domestic forest products increased from $4,189,000 in 1851 to $106,979,000 in 1914, the foreign or reexports increased from $567,000 to $4,518,000, and the imports increased from $1,333,000 to $155,261,000 for the same period. During the period 1851–1878 the average balance of trade in forest products was in favor of this country, but during 1879 and subsequently, except in 1901, the balance has been against the United States, due mostly to the large amount of india rubber imported.

The principal domestic farm and forest products exported from the United States during the five-year period, 1910–1914, are cotton, packing-house products, grain and grain products, and forest products, which represent over three-fourths of the total domestic farm and forest products exported. Cotton exceeded all other items in the value of domestic farm products exported, having an average annual value of $550,000,000; packing-house products, next in order, were valued annually at $155,000,000; grain and grain products, over $150,000,000; and forest products, $100,000,000. Other commodities, in the order of their importance, in the domestic export trade are: Tobacco, with an average annual value of $45,000,000; fruits, $28,000,000; oil cake and oil-cake meal, $24,000,000; vegetable oils, $21,000,000; live animals, $13,000,000; vegetables and coffee, $7,000,000 each; sugar, hops, dairy products, glucose and grape sugar, and starch, each averaging an annual value of $3,000,000.

The principal farm and forest products entering into the import trade of the United States during the five-year period, 1910–1914, are packing-house products, coffee, animal fibers, and sugar. The average annual value of each of these four articles exceeded $100,000,000, while their combined annual values amounted to over one-half of the total imports of farm and forest products. Other articles, in the order of their importance in the import trade, are: India rubber, with an annual average value of $86,000,000; vegetable fibers, excluding cotton, $40,000,000; tobacco, $30,000,000; fruits, $29,000,000; vegetable oils, $28,000,000; seeds, $22,000,000; cotton, $21,000,000; gums, other than india rubber, and alcoholic liquors, each $20,000,000; cocoa and chocolate, tea, wood pulp, and nuts, each valued at over $15,000,000; dairy products and live animals, each $9,000,000.

LEADING COUNTRIES.

UNITED KINGDOM.

The United Kingdom leads all the countries in the world as a market for the domestic farm and forest products of the United States. During the last 10 years the United Kingdom averaged annually 39 per cent of all farm and forest products exported.

Nearly one-half of the cotton exported was taken by this market during the five years 1910–1914, averaging annually 1,750,000,000 pounds, valued at $220,000,000. Three-fourths of the hops exported, one-half of the glucose and grape sugar, live animals, sugar, and starch, one-third of the packing-house products, grain and grain products, tobacco, and dairy products are sent to the United Kingdom.

During the five-year period 1910–1914 an annual average of one-third of the wheat, which is the leading grain exported, amounting to over 20,000,000 bushels; one-fourth of the corn, amounting to 11,000,000 bushels; and three-fourths of the barley, or 5,000,000 bushels, were consigned to the United Kingdom. Ninety per cent of the grain products exported went to that country, of which wheat flour was the largest item, having an annual average of 3,000,000 barrels, valued at $14,000,000.

The value of wood (logs, lumber, hewn and sawed timber) exceeds that of all other forest products exported, and of this the United Kingdom receives nearly one-fourth, amounting to $80,000,000 annually. Of the naval stores, the United Kingdom takes about one-fifth of the rosin exported amounting annually to 500,000 barrels, valued at $3,000,000, and almost one-half of the spirits of turpentine, or 7,000,000 gallons, valued at $3,000,000.

In the import trade of the United States the United Kingdom takes fourth place, first, second, and third places being held by Cuba, Brazil, and Japan. The value of india rubber exceeds that of all other articles imported and was valued at $28,000,000. Packing-house products were valued at $13,000,000, of which $8,000,000 were hides and skins. One-third of the wool, amounting to 69,000,000 pounds, valued at $15,000,000; one-fourth of the vegetable oils, valued at $6,000,000; over one-fourth of the alcoholic liquors, valued at $5,000,000; also tea, 12,000,000 pounds, valued at $3,000,000; vegetables, feathers and downs, and mahogany, each amounting to $2,000,000 annually, came from that country.

GERMANY.

During the last 10 years Germany averaged annually about 18 per cent of the total farm and forest products exported from the United States. Of these products the leading articles are cotton, packing-house products, grain and grain products, forest products, oil cake and oil-cake meal, fruits, and alcoholic liquors.

During the five-year period, 1910–1914, Germany took 28 per cent of the cotton, amounting to an annual average of 1,000,000,000 pounds, valued at $150,000,000; about one-eighth of the packing-house products, valued at $25,000,000; nearly one-third of the lard, amounting to 142,000,000 pounds, valued at $16,000,000; one-third of the sausage casings, or 14,000,000 pounds, valued at $2,000,000; one-sixth of the oleo oil, or 20,000,000 pounds, valued at $2,000,000; and one-fourth of the hides and skins, amounting to 7,000,000 pounds, valued at $700,000; also our exports to Germany in 1910–1914 included an annual average of 6,000,000 bushels of wheat, valued at $6,000,000; 5,000,000 bushels of corn, valued at $3,000,000; over one-half of the dried grains and malt sprouts, or 30,000 tons,[1] valued at $800,000; and one-half of the mill feed, or 96,000 tons, valued at $3,000,000. Of the forest products exported, Germany took naval stores valued at over $5,000,000, consisting of 700,000 barrels[2] of rosin, with a value of $4,000,000, and 2,900,000 gallons of spirits of turpentine, valued at $1,400,000.

FRANCE.

France held third place in the export trade of the United States during the last 10 years, and has received annually about one-sixth of the domestic farm and forest products. That country took, annually during the five years 1910–1914, over 500,000,000 pounds of cotton, valued at $70,000,000; $3,000,000 each of forest products, packing-house products, and grain and grain products; $1,000,000 each of fruits, oil cake and oil-cake meal, and vegetable oils.

Leading farm and forest products imported from France are: Packing-house products, alcoholic liquors, vegetable oils, gums, nuts, wool, vegetables, silk, seeds, argols or wine lees, live animals, nursery stock, and vanilla beans.

BRAZIL.

As a destination for agricultural products, Brazil was exceeded by 9 countries in 1905 and by 18 countries in 1914. Consignments to Brazil of this class of merchandise were valued at $2,144,000 in 1905 and $4,714,000 in 1914, of which the principal item was wheat flour, valued at $1,226,000 in 1905 and $3,752,000 in 1914.

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[1] Tons used in this bulletin are tons of 2,240 pounds.

[2] Barrels of 280 pounds for rosin, tar, turpentine, and pitch.

As a source of supply for agricultural products Brazil held second place, being exceeded by Cuba. The imports from Brazil in 1914 were valued at $84,187,000, of which $76,016,000 was coffee. The principal forest product imported from Brazil is india rubber; it was worth 16 million dollars in 1914.

OTHER COUNTRIES.

During the fiscal years 1910–1914 Canada received three-fourths of the horses and oranges, one-half of the raisins and peanuts exported, and supplied one-half of the sheep, butter, and wood pulp, 90 per cent of the lumber, all of the cream and pulp wood imported; Argentina supplied one-fourth of the cattle hides, 90 per cent of the quebracho extract and quebracho wood; the Netherlands took one-half of the oleo oil, one-fourth of the cottonseed oil, and supplied one-half of the nursery stock; Belgium took one-third of the flaxseed oil cake and wood pulp; Italy was the source of one-third of the cheese, one-half of the argols or wine lees, three-fourths of the hemp, filberts, and olive oil, 90 per cent of the macaroni, lemon oil, and ground sumac; Cuba was the destination for two-thirds of the eggs, one-third of the lard compounds, one-half of the coffee and potatoes, and supplied one-half of the beeswax and honey, 90 per cent of the molasses, three-fourths of the sugar, and two-thirds of the tobacco; Spain was the source of 90 per cent of the grapes and olives and one-half of the almonds; Japan was the source of one-half of the silk, rice, and tea, and 90 per cent of the camphor gum; Mexico took one-fourth of the malt, and supplied three-fourths of the cattle, 90 per cent of the istle or Tampico fiber and sisal grass, and all of the guayule gum; Egypt supplied three-fourths of the cotton; Russia three-fourths of the horse hides; British India three-fourths of the buffalo hides, one-half of the goatskins, 90 per cent of the jute and jute butts and shellac; and the Philippine Islands was the source of 95 per cent of the manila fiber.

LIVE ANIMALS.

The principal countries to which the United States has exported live animals are Canada, Mexico, and the United Kingdom. Exports of live animals to all countries were valued at $298,000 in 1855; $2,626,000 in 1858; $15,882,000 in 1880; $33,638,000 in 1890; $43,585,000 in 1900; then the exports declined and amounted to only $5,804,000 in 1914. The live animals exported were cattle, horses, mules, sheep, swine, and other, including fowls.

The imports were cattle, horses, sheep, and other, including fowls. The import value of live animals was $367,000 in 1855; $1,408,000 in 1858; $4,710,000 in 1880; $6,767,000 in 1890; decreased to $4,531,000 in 1900 and increased to $24,712,000 in 1914. Prior to 1877 the imports of live animals exceeded the exports in value; from 1878 to 1912 the imports were less than the exports, amounting to less than one-tenth for a portion of the period, but in 1914 the imports were four times the value of the exports.

Cattle.—The cattle exported during the 10 years 1884–1893 averaged 234,914 head annually. The greater portion of these went to the United Kingdom, amounting to 218,752 head, or 93.1 per cent. The next 10-year period, 1894–1903, the United Kingdom received 332,134 head, or 84.4 per cent. The next 10-year period, 1904–1913, the United Kingdom received 233,987 head, or 74.4 per cent. During 1914, 18,376 cattle were exported, of which nearly 9,000 went to Canada and 7,000 to Mexico. During the 10-year period 1884–1893 these three countries supplied more than 98 per cent of the cattle imported, the percentage being 56.5 for Canada, 40.9 for Mexico, 1.2 for the United Kingdom. During the next 10 years these three countries supplied 99 per cent of the imported cattle; 29.2 per cent came from Canada, 70.6 per cent from Mexico, and a small quantity from the United Kingdom. During the 10 years 1904–1913 these three countries again supplied about 99 per cent of the imported cattle, the percentage being 6.6 per cent for Canada, 92.9 per cent for Mexico, and 0.05 per cent for the United Kingdom. In 1914, 868,368 cattle were imported, of which 27.8 per cent came from Canada, 72 per cent from Mexico, and 0.2 per cent from the United Kingdom.

Horses.—The exports of horses during the 10 years 1884–1893 were consigned chiefly to three countries, Canada, Mexico, and Cuba. Canada received 38.6 per cent; Mexico, 29 per cent; and Cuba, 1.2 per cent. The average annual exports for that period were 2,671 head. From 1894 to 1903 the annual exports were 46,482, of which 22.1 per cent were consigned to Canada, 3 per cent to Mexico, and 4.8 per cent to Cuba. During the 10 years 1904–1913 the annual exports amounted to 30,900, of which 77.3 per cent were consigned to Canada, 5.9 per cent to Mexico, 7.6 per cent to Cuba. In 1914, 22,776 horses were exported, of which 17,700 were consigned to Canada.

The imports of horses during the three 10-year periods, 1884 to 1913, were supplied chiefly by Canada and Mexico. During the 10 years 1884–1893, 42,351 horses were imported annually, of which 42.4 per cent came from Canada, 48.2 per cent from Mexico, and 3.8 per cent from the United Kingdom. During the next 10 years, 1894–1903, the annual imports were 5,910, of which 74.6 per cent were supplied by Canada, 12.2 per cent by Mexico, and 5.3 per cent by the United Kingdom. During 1904–1913 the annual imports were 7,241, of which Canada supplied 36.2 per cent; Mexico, 14.9 per cent; and the United Kingdom, 14 per cent. In 1914 the imports were 33,019, of which 13.4 per cent came from Canada, 77.5 per cent from Mexico, and 0.2 per cent from the United Kingdom.

Mules.—The exports of mules have about equaled in number the exports of horses. For the 10-year period 1884–1893 the annual exports of mules were 2,299. For the next 10-year period, 1894–1903, the annual exports averaged 14,248, of which 12.7 per cent were consigned to Cuba. During 1904–1913 the annual exports averaged 5,422, and in 1914 they were 4,883, of which 1,399 were consigned to Cuba, 1,256 to Mexico, and 1,039 to Canada.

Sheep.—The exports of sheep have been consigned chiefly to three countries—Canada, Mexico, and the United Kingdom. During the 10-year period, 1894–1903, the annual exports were 257,589 head, of which 23.4 per cent went to Canada, 1.2 per cent to Mexico, and 71.5 per cent to the United Kingdom. For the last 10-year period, 1904–1913, the exports were 152,677 head annually, of which 50.5 per cent went to Canada, 3.8 per cent to Mexico, and 42.2 per cent to the United Kingdom. During 1914 the exports were 152,600, of which 145,715 were consigned to Canada.

The sheep imported were nearly all supplied by Canada during the last 30 years. During the 10-year period, 1894–1903, the annual imports were 328,244, of which 96 per cent came from Canada. During the 10 years, 1904–1913, the annual imports were 143,663, of which Canada supplied 92.9 per cent. During 1914 the imports were 223,719, of which 7.8 per cent came from Canada and 91.8 per cent from Mexico.

Swine.—The swine have been sent chiefly to three countries—Canada, Cuba, and Mexico. During the 10 years, 1894–1903, the annual exports were 19,182, of which 9.5 per cent went to Canada, 44.1 per cent to Cuba, and 34.8 per cent to Mexico. During the next 10 years those three countries received nearly an equal amount, the average exports to all countries being 23,108, of which 32.8 per cent went to Canada, 40.4 per cent to Cuba, and 24.5 per cent to Mexico.

DAIRY PRODUCTS.

The foreign trade in dairy products consists of butter, cheese, cream, fresh and condensed milk. The total export value of these products in 1851 was 1 million dollars, which increased to nearly 23 million dollars in 1881, and decreased to a little less than 3 million dollars in 1914. The import value was slightly more than $100,000 in 1851, and increased to 1 million dollars in 1884, 6 million dollars in 1907, and 15 million dollars in 1914.

Butter.—The quantity of butter exported ranged from 31 million pounds in 1897 to 4,000,000 pounds in 1914. During the period 1896–1909 about one-half of the butter was consigned to the United Kingdom. During 1910–1914 about two-thirds of the butter was consigned to Canada, Panama, Mexico, and the West Indies. Venezuela has been a good market for butter during the last 20 years, receiving about one-half million pounds annually.

Canada has been the chief source of supply for butter imported into the United States. The imports from that country during the five-year period 1895–1899 were 74.7 per cent of all imports. During 1900–1904 that country supplied 51.6 per cent; 1905–1909, 45 per cent; 1910–1914, 25 per cent. Other countries in 1914 supplying large quantities of butter were Denmark, United Kingdom, and New Zealand. The imports of butter for the five years ending 1914 ranged from a little over 1 million pounds in 1910 to nearly 8 million pounds in 1914.

Cheese.—The cheese exports have ranged from 60 million pounds in 1895 to a little less than 2½ million pounds in 1914, of which about three-fourths were sent to the United Kingdom. Other good markets during the last five years were Canada, Cuba, Mexico, Panama, and the British West Indies.

The imports of cheese for the last 20 years have ranged from 10 million pounds in 1895 to 64 million pounds in 1914. The annual imports during the five years 1895–1899 were more than 11 million pounds; 1900–1904, nearly 18 million pounds; 1905–1909, more than 30 million pounds; 1910–1914, 49 million pounds. Italy and Switzerland each supplied about one-third during the 20 years just mentioned. Other countries supplying large quantities during the same period were France, Germany, Greece, and the Netherlands. The average annual imports from Italy ranged from a little over 3 million pounds during 1895–1899 to nearly 21 million pounds during 1910–1914. The average annual supply from Switzerland ranged from 5 million pounds during the five years 1895–1899 to nearly 17 million pounds during 1910–1914.

Cream.—More than one-half of the milk, including cream, was sent to Canada, and was valued at $245,000 in 1912, $474,000 in 1913, and $333,000 in 1914. The imports of cream in 1910 were 731,783 gallons, 2,333,000 gallons in 1911, 1,121,000 gallons in 1912, 1,247,000 gallons in 1913, and 1,773,000 gallons in 1914. Practically all of this product came from Canada, the percentage being 99.99. The average import value was about $1 per gallon.

Milk.—The quantity of condensed milk exported has only been shown for the last five years. The exports were 13 million pounds in 1910 and 16 million pounds in 1914. Cuba received nearly one-half of this article, and other good markets were Panama, Mexico, China, Asiatic Russia, and the Philippine Islands. Imports of milk, fresh and condensed, were valued at $63,000 in 1910, increasing to $1,089,000 in 1914. The United Kingdom and Canada have been the chief sources of supply for this product.

PACKING-HOUSE PRODUCTS.

The exported products of the slaughtering, or "packing-house," industry consist chiefly of fresh and cured meats, fats, and oils. The exports reached their highest point about 10 years ago, and have been on a general decline ever since. The total exports of beef and pork exported in 1906 were 2,198 million pounds, which decreased to less than one-half, or 1,070 million pounds, in 1914. The beef products increased from 33 million pounds during the five years, 1852–1856, to 733 million pounds in 1906, and decreased to 148 million pounds in 1914. The pork products increased from 104 million pounds during the five years, 1852–1856, to 1,465 million pounds in 1906, and decreased to 922 million pounds in 1914. The value of the packing-house products about equals the value of the surplus cereal products and exceeds the total value of all forest products exported.

MEAT.

The value of the meat exported has been many times the value of the imports, but the imports of fresh meats in 1914 were in excess of the exports, the imports being 197,472,887 pounds, valued at $17,079,-442, and the exports 9,062,424 pounds, valued at $1,147,974.

Beef.—The exports of beef and its products were more than 33 million pounds annually during the five years 1852–1856; increased to 71 million pounds during 1862–1866; to 219 million pounds during 1877–1881; to 639 million pounds during 1897–1901; and decreased to 448 million pounds during 1907–1911. The largest quantity exported for any one year was 733 million pounds in 1906, decreasing to 148 million pounds in 1914.

The imports of beef and its products were 1,875,000 pounds, valued at $45,000, in 1900; 11,188,000 pounds, valued at $1,108,000, in 1910; and 185,381,000 pounds, valued at $15,884,000, in 1914. During 1914 Argentina supplied 59,775,000 pounds; the United Kingdom, 57,540,000 pounds; Uruguay, 25,903,000 pounds; Australia, 19,859,000 pounds; and Canada, 15,920,000 pounds.

Canned beef.—The canned beef exported in 1887 was 43 million pounds, which increased to 110 million pounds in 1891, and decreased to 76 million pounds in 1903, and to 3 million pounds in 1914. The United Kingdom has been our best market for canned beef, taking about three-fourths of this product 20 years ago and about one-half during the last five years. During the five years, 1910–1914, the United Kingdom was the only country to which more than 1 million pounds were consigned for any one year, the range being from 9 million pounds in 1910 to 1 million pounds in 1914.

Cured or pickled beef.—The cured beef exported in 1866 amounted to 19 million pounds, which increased to 98 million pounds in 1890, and decreased to 23 million pounds in 1914. The five principal countries to which this was consigned during the last five years, in their order, were United Kingdom, Newfoundland and Labrador, Germany, Belgium, and British West Indies.

Fresh beef.—The fresh beef exported in 1877 amounted to 49 million pounds, which increased to 352 million pounds in 1901, and decreased to 6 million pounds in 1914. From 1894 to 1911 practically all of this product was consigned to the United Kingdom. For 1912 the United Kingdom received one-half and Panama one-third; for 1913 and 1914 Panama received about three-fourths.

The imports of fresh beef and veal in 1900 were 337,000 pounds, valued at $17,000; in 1910, 949,000 pounds, valued at $64,000; in 1914, 180,137,000 pounds, valued at $15,424,000. During 1914 Argentina supplied 60 million pounds; the United Kingdom, 58 million pounds; Uruguay, 26 million pounds; Australia and New Zealand, 21 million pounds; and Canada, 16 million pounds.

Beef fats and oils.—Oleo oil exported in 1882 amounted to 20 million pounds, increased to 212 million in 1908, and decreased to 97 million pounds in 1914. A little more than one-half of the total exports have been consigned to the Netherlands during the last 20 years, part of which were probably reshipped from the Netherlands to other countries. Other countries to which large consignments were sent were Germany, Denmark, Norway, and the United Kingdom. The value of this product increased from 3 million dollars in 1882 to 19 million dollars in 1908, and decreased to a little more than 10 million dollars in 1914.

Oleomargarine.—The oleomargarine exported in 1882 amounted to more than 2 million pounds, which increased to nearly 12 million pounds in 1906, and decreased to 2½ million pounds in 1914. During the last five years nearly all of this product was consigned to North American countries, chiefly the subtropical countries of the West Indies and the Central American States.

Stearin.—The export data of stearin from animal fats are only available for 1913 and 1914, the exports being 3,745,000 pounds for 1913, and 2,724,000 pounds for 1914. Canada received about one-third of this product and the remainder was consigned chiefly to Belgium, Germany, the Netherlands, Mexico, and Cuba.

Oleo stearin.—During the five years ending with 1914 the imports of oleo stearin averaged 6,705,522 pounds annually, of which five countries supplied 88 per cent. The five countries and the average annual imports from each in their order were Argentina 1,579,160 pounds, United Kingdom 1,282,708 pounds, the Netherlands 1,082,289 pounds, Italy 999,727 pounds, and France 956,366 pounds.

Tallow.—The beef tallow exported during the five-year period 1852–1856 amounted to 7 million pounds annually, which increased to

97 million pounds in 1877–1881, and again increased to 128 million pounds in 1907. This product gradually declined to a little less than 16 million pounds in 1914. The United Kingdom, the Netherlands, Germany, France, and Belgium have been the best markets for tallow.

Pork products.—Exports of pork and its products amounted to 104 million pounds annually during the five-year period 1852–1856, increasing to 1,467 million pounds in 1906 and decreasing to 923 million pounds in 1914. During the 20-year period 1892–1911, the pork products exported averaged more than 1 billion pounds annually. For the years 1901 and 1909 the annual exports ranged from 1,042 million pounds to 1,465 million pounds. The billion mark was again reached in 1912, the exports being 1,072 million pounds.

The imports of pork and its products were 320,000 pounds, valued at $54,000, in 1900; 659,000 pounds, valued at $147,000, in 1910; 6,634,000 pounds, valued at $924,000, in 1914. During 1914 Canada supplied 89 per cent, amounting to 5,917,000 pounds, valued at $749,000.

The exports of canned pork in 1900 were a little more than 8 million pounds, which increased to nearly 14 million pounds in 1903 and decreased to a little more than 3 million pounds in 1914. The United Kingdom has been the best market for this class of meat, receiving a little more than three-fourths during the last five years.

The exports of bacon amounted to 18 million pounds in 1851, increased to 760 million pounds in 1880, and gradually declined to 194 million pounds in 1914. During the five years ending with 1914 about three-fourths of this class of meat was consigned to the United Kingdom. Cuba received as much as all the other countries of North America combined, and Brazil received about 90 per cent of the bacon consigned to countries of South America. The countries purchasing more than 1 million pounds annually during the last five years were the United Kingdom, Belgium, Italy, the Netherlands, Canada, Cuba, and Brazil. The average export value of bacon ranged from 18 million dollars in 1910 to nearly 26 million dollars in 1914.

Bacon and hams imported were 287,697 pounds, valued at $50,009, in 1900; 2,008,960 pounds, valued at $383,669, in 1914. During 1914 more than half, or 1,314,093 pounds, came from Canada, 222,226 pounds from Germany, 223,862 pounds from the United Kingdom, and 178,286 pounds from the Netherlands.

The hams and shoulders exported amounted to 48 million pounds annually during the five years 1882–1886, which was doubled ten years later, or during 1892–1896, the annual exports being 96 million pounds, and again doubled during the next five years, 1897–1901, the exports being 201 million pounds. Approximately 90 per cent went to the United Kingdom during the last 20 years, 1895–1914. During the same period Belgium received an annual average of about 5 million pounds, Cuba 4 million pounds, and Canada 3 million pounds.

Fresh pork exported in 1884 amounted to 185,000 pounds, which increased to 44,000,000 pounds in 1902 and decreased to 2,668,000 pounds in 1914. During the 15 years 1895–1909 about 90 per cent of this product went to the United Kingdom. During the five years 1910–1914, 35 per cent of the fresh pork was consigned to the United Kingdom, 26 per cent to Panama, and 20 per cent to Canada. The fresh pork imported in 1914 amounted to 4,624,799 pounds, valued at $540,801. Canada supplied 4,600,000 pounds and Russia 21,000 pounds.

The annual exports of salted or pickled pork during the five years 1852–1856 averaged 41 million pounds, which was doubled 25 years later, or during 1877–1881, amounting to 86 million pounds; this amount was again doubled 20 years later, or in 1907, the amount being 166 million pounds, which decreased to less than one-third, or 52 million pounds, in 1909, and to 46 million pounds in 1914. In 1895 the United Kingdom received about one-fourth of this article, or 14 million pounds. Ten years later, or during 1904, this was increased to about one-half, or 58 million pounds. After a lapse of another 10 years, or in 1914, the proportion to the United Kingdom was reduced to about one-eighth, or 5 million pounds. In 1896 four countries—the United Kingdom, Canada, Haiti, and the British West Indies—received 10 million pounds each. In 1914 the same countries received 5 million pounds, 13 million pounds, 1½ million pounds, and 5 million pounds, respectively.

Lard.—The exports of lard in 1851 amounted to 20 million pounds. Ten years later this was doubled, amounting to 40 million pounds, and continued to increase until 1906, when the quantity amounted to 742 million pounds, which decreased to 481 million pounds in 1914. In 1895, 184 million pounds were consigned to the United Kingdom and 104 million pounds to Germany. Ten years later, or in 1905, 229 million pounds were consigned to the United Kingdom and 188 million pounds to Germany. After a lapse of another 10 years the consignments decreased to 165 million pounds to the United Kingdom and to 146 million pounds to Germany. During the five years, 1910–1914, the value of the lard exported formed about one-half of all the pork products sent abroad.

Neutral lard exported in 1911 amounted to 38 million pounds, increased to 62 million pounds in 1912, and decreased to 45 million pounds in 1913, and to 29 million pounds in 1914. The Netherlands was the leading country to which this product was consigned, taking approximately one-half of the neutral lard exported. Denmark, Germany, Norway, and the United Kingdom received the greater portion of the remainder.

The lard oil exported increased from 103,000 gallons in 1855 to 1,963,000 gallons in 1879, and decreased to 111,000 gallons in 1914. During the five years, 1910–1914, the greater portion of this product was consigned to three countries, Germany, the United Kingdom, and Mexico.

Lard compounds.—The lard compounds exported in 1893 were 912,000 pounds. During the next 10 years, or in 1903, this product had increased 500 per cent, amounting to more than 46 million pounds, and continued to increase to more than 58 million pounds in 1914. The United Kingdom has been the best market for this article, receiving about 90 per cent in 1895 and about 40 per cent in 1914. Other countries receiving large quantities during recent years were Mexico, Cuba, Haiti, and Chile.

Mutton.—The exports of mutton in 1877 amounted to 349,000 pounds. This was increased to 1,440,000 pounds in 1879, to 3,356,000 in 1885, then gradually decreased to 101,463 pounds in 1892. Increased again to more than 2 million pounds in 1894 and to 6 million pounds in 1903. During the last five years the exports have ranged from 1,989,000 pounds in 1910 to 4,685,000 pounds in 1914. Twenty years ago the United Kingdom was the best market for this class of meat, but during the last five years Canada has been the better market, receiving a little more than one-half during that period. A large quantity was also consigned to the United Kingdom and Panama.

The fresh mutton and lamb imported in 1914 amounted to 12,710,905 pounds and was valued at $1,114,730. Argentina supplied 5 million pounds; Australia and New Zealand, 4 million pounds; Uruguay, 2 million pounds; and the United Kingdom, 1,305,000 pounds.

Miscellaneous meats.—The canned-meat products exported in 1900 were valued at $1,724,000. This article has not fluctuated much in value since that time, the average annual exports being slightly more than $1,000,000, amounting in 1914 to $1,350,000. During the last five years about one-half of this product has been consigned to the United Kingdom.

Exports of canned sausage meat during 1913 and 1914 amounted to a little more than 1 million pounds, of which about one-half was sent to Cuba; also large quantities were consigned to the Philippine Islands and British South Africa. Sausage meats, other than canned, for 1913 amounted to nearly 7 million pounds, and decreased to a little less than 5 million pounds in 1914. This product was consigned chiefly to France, Canada, Cuba, and Belgium. This item included the canned sausage exported in 1901 and amounted to nearly 10 million pounds, decreasing to 8 million pounds in 1912.

The value of poultry and game exported in 1895 was $17,898, which increased to $1,397,000 in 1906 and decreased to $914,000 in 1914.

During the last five years, 1910–1914, about 90 per cent of this product went to the United Kingdom. Canada and Panama each received large consignments.

Various other meat products exported ranged in value during the five years, 1910–1914, from $1,362,000 to $1,936,000. About three-fourths of this class of meat products were consigned to the United Kingdom. Other countries receiving large quantities were Belgium, Canada, Panama, British West Indies, Cuba, and Haiti.

Imports of bologna sausage in 1878 were valued at $27,554, which gradually increased to $186,824 in 1914. The quantity imported was first shown in 1906, the amount being 744,634 pounds, which decreased to 730,326 pounds in 1914. The average annual imports for the nine years were 658,935 pounds, of which 75 per cent came from Germany.

The miscellaneous prepared or preserved meats imported in 1914 were valued at $1,676,360. Nearly one-half of these meats came from Australia and New Zealand, amounting to $761,325; Canada supplied $255,881, the United Kingdom $194,288, and Argentina $148,096.

HIDES AND SKINS.

The exports of hides and skins from the United States has been unimportant when compared with the imports. Furs are not included in this classification. The quantity exported in 1895 was a little more than 36 million pounds. This decreased to 7 million pounds in 1900 and increased to nearly 20 million pounds in 1914. The export hides and skins have been consigned chiefly to Germany and Canada during the last five years. Twenty years ago, or in 1895, Canada received one-half of our hides and skins.

The large production of hides and skins in this country has never been equal to the demand, for the imports have annually been far in excess of exports. Compared with other countries, this country held first place in the world trade in this article, receiving one-fourth of the hides and skins imported into all countries during the calendar years 1911–1913. The first year for which the total weight of hides and skins was shown in our foreign trade was in 1895, the exports being 36,002,859 pounds and the imports 226,575,745 pounds. A similar comparison for other years exhibits a still greater contrast. The exports have decreased almost one-half, while the imports have more than doubled. The exports in 1914 amounted to 19,867,135 pounds and the imports were 561,070,686 pounds.

Buffalo hides.—Prior to 1911 the imports of buffalo hides were included with cattle hides, the imports for that year being 3,599,386 pounds, 4,988,675 pounds in 1912, 16,234,751 pounds in 1913, and 14,492,943 pounds in 1914. The British East Indies supplied 90.9 per cent of this class of hides during the last four years.

Calfskins.—The calfskins exported in 1912 amounted to more than 500,000 pounds, and increased to 900,000 pounds in 1913, but decreased to 323,000 pounds in 1914. Nearly all of these were consigned to Canada.

Imports of calfskins were separately stated for the first time in 1910, and since that time the imports have averaged 83,518,403 pounds annually. Eight countries supplied 83 per cent of this kind of hides. The countries and the average annual supply from each were: Russia, 22,419,150 pounds; Germany, 16,567,590 pounds; the Netherlands, 7,839,510 pounds; Canada, 6,267,359 pounds; France, 4,874,163 pounds; Belgium, 4,238,167 pounds; Denmark, 4,182,108 pounds; and Argentina, 2,929,755 pounds.

Cattle hides.—More than half of the cattle hides were consigned to Canada during the three years 1912–1914, the exports being 17 million pounds for 1912 and 1913, and 13 million pounds for 1914, of which Canada received 11 million pounds during each of the years 1912–1913 and nearly 8 million pounds in 1914.

The imports of cattle hides increased from 126 million pounds in 1898 to 280 million pounds in 1914. Three countries of South America—Argentina, Uruguay, and Venezuela—have been the source of about one-third of the cattle hides imported during the last 17 years. In 1898 Argentina and the United Kingdom each supplied a little less than 20 million pounds. In 1914 Argentina had increased to 80 million pounds, while the United Kingdom had decreased to 11 million pounds. This product came from practically every country on the globe, but the eight principal countries were Argentina, British East Indies, Canada, France, Mexico, the United Kingdom, Uruguay, and Venezuela.

Goatskins.—The quantity of goatskins imported in 1895 amounted to 54 million pounds, which increased to 111 million pounds in 1906 and decreased to 85 million pounds in 1914. The yearly imports were 57 million pounds during 1895–1899, 83 million pounds during 1900–1904, and 96 million pounds during 1905–1914. British East Indies, China, France, Mexico, and European Russia supplied slightly less than one-half of this item during 1895–1899 and increased to about two-thirds during 1910–1914. The imports from British East Indies increased from 18 per cent 20 years ago to 43 per cent during the last five years.

Horsehides.—The horsehides exported during 1913–14 amounted to more than 5 million pounds for each year. About 90 per cent of these were consigned to Germany, the exports to that country being 4,924,000 pounds in 1913 and 5,055,000 pounds in 1914.

The quantity of horse and ass skins imported during the last five years has averaged 14,865,419 pounds annually, of which Russia supplied annually 6,724,976 pounds, or 45.2 per cent, and Canada 1,447,265 pounds, or 9.7 per cent. France, Germany, and the United Kingdom were important as a source for this class of hides and skins.

Kangaroo skins.—Imports of kangaroo skins for 1913 and 1914 came chiefly from Australia. That country supplied 1,064,918 pounds in 1913 and 1,265,904 pounds in 1914. The total imports from all countries were 1,097,038 pounds in 1913 and 1,328,668 pounds in 1914.

Sheepskins.—Sheepskins imported in 1909 amounted to 49 million pounds, which increased to more than 70 million pounds in 1913 and 1914. The annual average imports for the six years were 62,381,892 pounds, of which 27,781,488 pounds, or 44.5 per cent, annually came from the United Kingdom. Other countries that supplied large quantities of sheepskins during that period were France, European Russia, Argentina, Canada, British India, Australia, and New Zealand.

Hide cuttings.—Imports of hide cuttings, raw, and other glue stock were valued at $1,605,432 in 1910 and increased to $2,158,514 in 1914. More than $1,000,000 annually came from European countries, chiefly France, Germany, Italy, and the United Kingdom.

MINOR PRODUCTS OF THE SLAUGHTERING INDUSTRY.

Grease and oils.—The grease and grease scraps consigned to foreign countries have been divided during the last three years into two classes—the grease for lubricating purposes and grease for soap making. The grease for lubricating purposes was valued at $2,193,000 in 1912 and $2,395,000 in 1914. This product was mostly consigned to Germany, the Netherlands, the United Kingdom, and Canada. The grease for soap making was valued at $4,486,000 in 1912 and $5,047,000 in 1914, and was consigned chiefly to Belgium, France, Germany, Italy, the Netherlands, the United Kingdom, Canada, and Cuba.

During the last three years imports of grease not specified was supplied chiefly by six countries—Belgium, France, Germany, the United Kingdom, Canada, and China. The imports in 1912 were valued at $963,205 and in 1914 at $1,028,595.

Hair and bristles.—The exports of unmanufactured animal hair were valued at slightly more than one-half million dollars in 1895, which gradually increased to $1,165,000 in 1908 and to $1,449,000 in 1913 and decreased to $1,085,000 in 1914. Prior to 1913 this article contained a small quantity of manufactures of hair. European countries have received the greater portion of this product, the principal countries being Belgium, Germany, and the United Kingdom; also a large quantity was consigned to Canada.

The imports of horse hair in 1910 were 5,410,930 pounds; in 1911, 4,542,930 pounds; in 1912, 5,381,730 pounds; in 1913, 5,147,923 pounds; and in 1914, 3,738,836 pounds. European and South American countries have supplied 87 per cent of this product in the last five years—44.4 per cent came from Europe and 42.6 per cent from South America. The imports from Argentina exceeded those of any other country and amounted to an average of more than 1,228,000 pounds annually.

The average annual imports of bristles for the five years 1905–1909 were more than 2,800,000 pounds, and during the next five years, 1910–1914, these imports increased to more than 3,600,000 pounds. China and the United Kingdom supplied 61.2 per cent during the five-year period, 1905–1909, and 69.2 per cent during 1910–1914. Large quantities also came from France, Germany, Hongkong, and Russia.

Sausage casings.—Sausage casings exported in 1875 were valued at $135,000, which increased to more than $1,000,000 in 1893, to nearly $4,000,000 in 1908, and for the five years 1910–1914 the value ranged from a little less than 4 million to 5½ million dollars, of which Germany and the Netherlands received about 60 per cent during 1910–1914. The quantity exported is only shown for the last five years, and ranged from 26 million to 40 million pounds. Imports of sausage casings for the last five years were valued at an average of $2,634,735 annually, of which $1,637,347, or 62.1 per cent, came from the United Kingdom. Three other countries—Argentina, the Netherlands, and Germany—each supplied large quantities of this product.

Bones, hoofs, and horns.—The bones, hoofs, horns, horn tips, strips, and waste exported in 1895 were valued at $288,000. The next 10 years this had decreased to $181,000, and again decreased to $109,000 in 1914. This product was consigned chiefly to Belgium, France, Italy, and the United Kingdom.

The imports of unmanufactured bones, hoofs, and horns for the last five years have annually averaged over $1,000,000. These have been supplied chiefly by cattle-producing countries, such as Argentina, Canada, Mexico, and Uruguay. Argentina supplied 42.2 per cent of this product during the last five years. The cleaned bones imported for the last three years were valued at $18,512 in 1912, $40,612 in 1913, and $5,023 in 1914. The greater portion of these were supplied by Belgium and Canada.

Dried blood.—The dried blood imported in 1904 was valued at $23,671, and the value of this product did not exceed $100,000 until 1910, when it was valued at $221,587, and increased to $391,816 in 1914. Argentina, Australia, and the United Kingdom have been the source of more than half of this article during the last five years.

Bladders.—Imports of bladders, except fish, during the last four years have been valued at $38,129 in 1911, $41,954 in 1912, $96,237 in 1913, and $52,336 in 1914. Canada and Germany have been the source of more than half of this article during the last five years.

Rennets.—For the last 20 years the imports of rennets were valued at an average of $96,205 annually. Denmark supplied an annual average of $70,719, or 73.5 per cent. This product first appeared in the import trade of the United States in 1876, when the value amounted to $16,441. For the last five years the annual imports were $92,459 in 1910, $111,609 in 1911, $102,142 in 1912, $129,557 in 1913, and $129,720 in 1914.

OTHER ANIMAL PRODUCTS.

WOOL.

The exports of wool from the United States since 1852 have been in negligible quantities, the exports for that year being 55,550 pounds. The largest quantity exported for any one year was in 1896, the exports being nearly 7 million pounds. For 1901 and subsequently the exports have averaged only a few hundred thousand pounds annually, decreasing to so small a figure that it was not separately shown in the customs returns for 1911 and 1912, and amounted to 335,348 pounds in 1914.

As an importing country for wool during the 10 calendar years 1904–1913 the United States held fifth place among the countries of the world. The five leading countries importing wool were: France, 555 million pounds; United Kingdom, 487 million pounds; Germany, 458 million pounds; Belgium, 217 million pounds; and the United States, 198 million pounds. Our wool imports during the fiscal year 1840 amounted to nearly 10 million pounds. This was almost doubled in 1850 and continued to increase until during the last 20 years the imports have been approximately 200 million pounds annually. The annual production for the latter period has been close to 300 million pounds; thus the consumption of wool in the United States during that time has been about 500 million pounds annually, or about 5 pounds for each individual. The annual average imports of wool during the five years 1895–1899 were 199 million pounds; 1900–1904, 155 million pounds; 1905–1909, 209 million pounds; 1910–1914, 208 million pounds. As a source of supply for imports of wool eight countries have supplied the greater portion during the last 20 years. The supply from those eight countries during the 15 years 1895–1909 was 90 per cent of the wool imported, but for the last five years, 1910–1914, only 87 per cent came from those countries. As a source of supply the United Kingdom held first place, supplying 41.1 per cent during the five years 1895–1899, 34.2 per cent during 1900–1904, 30.7 per cent during 1905–1909, and 33.1 per cent during 1910–1914.

During the five years 1910–1914 an average of 27 million pounds annually came from Argentina, 17 million pounds from Australia, 33 million pounds from China, 4½ million pounds from New Zealand, 16 million pounds from European Russia, 10 million pounds from Asiatic and European Turkey, 69 million pounds from the United Kingdom, and 4½ million pounds from Uruguay. As a port of entry for imports of wool for recent years Boston exceeded all the other ports. New York was second and Philadelphia third.

SILK.

The largest quantity of silk waste exported from this country for any one year was 300,553 pounds in 1909, which decreased to 266,207 pounds the following year, and again decreased to 27,597 pounds in 1914. Four countries, China, France, Italy, and Japan, have been the chief source of our silk supply. Japan has annually supplied about one-half of the silk used in this country, which is mostly raw, in skeins, or as reeled from the cocoon. From 1871 to 1879 imports of this grade of silk averaged a little over 1 million pounds annually. These imports increased to more than 10 million pounds in 1898, 23 million pounds in 1909, and to nearly 29 million pounds in 1914. The average annual imports for all silk for the five years ending with 1909 were 20,060,664 pounds, of which 47.6 per cent was supplied by Japan, 20.2 per cent by Italy, 17.4 per cent by China, and 8.1 per cent by France. For the five years ending with 1914 the imports averaged annually 28,671,132 pounds, of which Japan supplied 55.4 per cent, China 22.2 per cent, Italy 11.4 per cent, and France 3.6 per cent.

EGGS.

The eggs consigned to foreign countries ranged from 1,300,000 dozen in 1897 to 20 million dozen in 1913, and decreased to 16 million dozen in 1914. Canada and Cuba have received about three-fourths of our eggs exported during the last 20 years. During the last 10 years Mexico has taken an average of more than half a million dozen annually, and since 1908 Panama has taken a like amount. Prior to 1897 the imports greatly exceeded the exports, but since that time the reverse has been the case.

The imports of eggs in 1872 were a little less than 5 million dozen, which increased to 16½ million dozen in 1884, and decreased to less than 3 million dozen in 1895. This product continued to decrease to a little more than 231,000 dozen in 1907, and again increased to more than 6 million dozen in 1914. Twenty years ago, or in 1895, nearly all of the imported eggs came from Canada, but for the last five years the United Kingdom has been the chief source of supply. During 1914 Austria-Hungary supplied more than 1 million dozen;

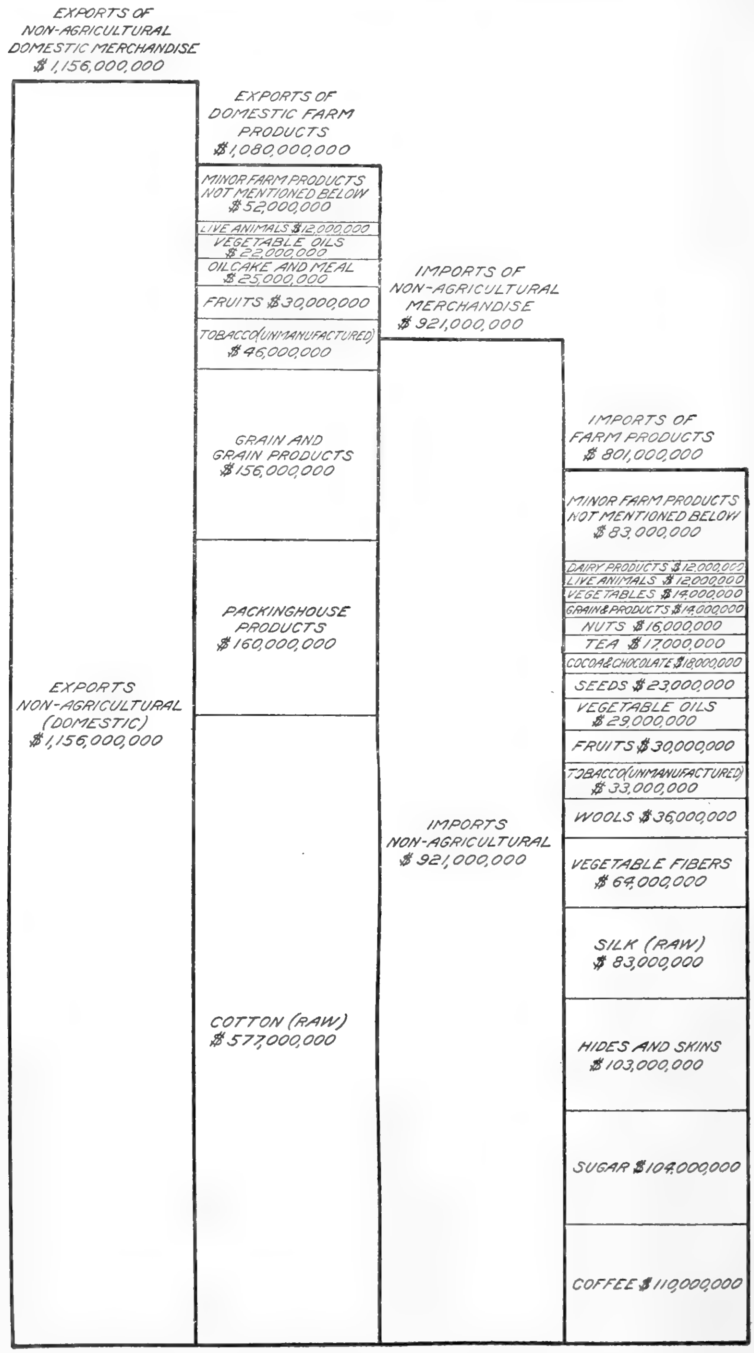

Fig. 1.—Average annual value of agricultural and nonagricultural products in the trade of the United States with foreign countries during the fiscal years ending June 30, 1911–1914.

Germany, 1,847,000 dozen; and China, 1,875,000 dozen. Other countries supplying large quantities of eggs in 1914 were Russia, the United Kingdom, Canada, and Hongkong.

The exports of egg yolks, canned eggs, etc., appeared in our export trade in 1892 when the exports were valued at $5,500. The trade in this product has been unimportant. For some years there were

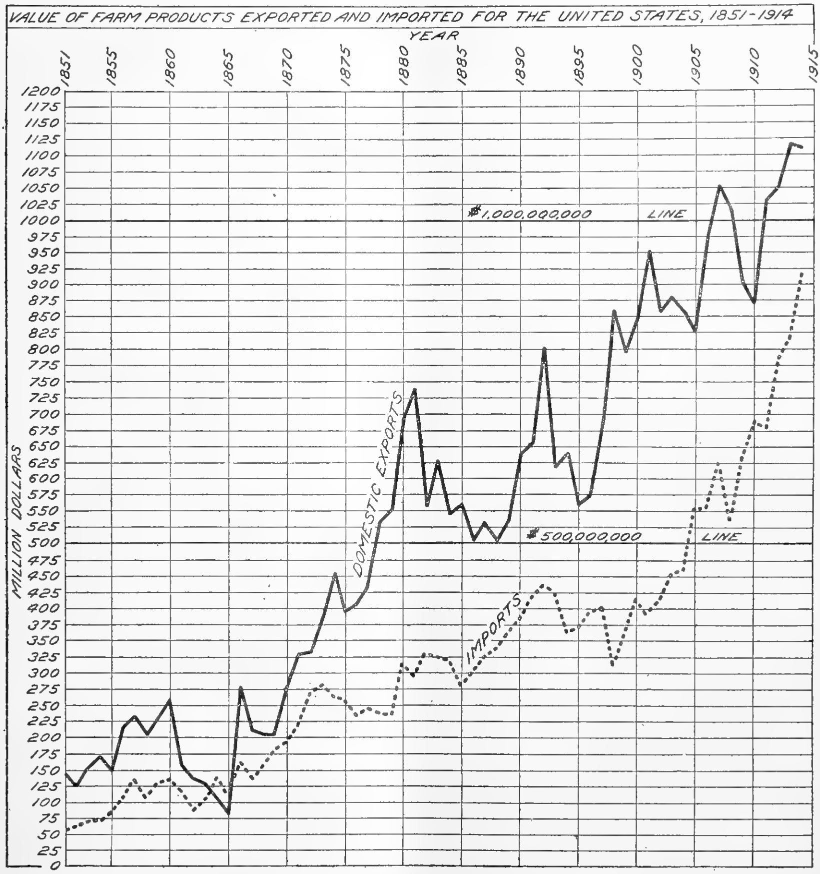

FIG. 2.—Exports and imports of agricultural products for the United States during the fiscal years ending June 30, 1851–1914.

no exports. The exports in 1913 were valued at $67,854, which exceeded all previous years. In 1877 the imports were valued at $2,529. The largest quantity imported for any one year was 3,420,412 pounds in 1914, valued at $504,619. In 1914 more than one-half of this product exported was sent to Canada and nearly two-thirds of the imports came from the United Kingdom.

HONEY AND BEESWAX.

The quantity of honey exported has not been stated, but the yearly export value for the five years ending with 1899 was $77,323, which was doubled during the five years ending with 1914 and amounted to $154,325. Germany and the United Kingdom have received more than one-half of the honey exported during the last 20 years. Other countries receiving important consignments of this product since 1905 were Canada and the Netherlands.

The quantity of honey imported has ranged from 66,432 gallons in 1897 to 287,696 gallons in 1903. The annual imports during the last five years have averaged a little more than 100,000 gallons. Mexico and Cuba supplied 83.2 per cent, of which 40.3 per cent came from Mexico and 42.9 per cent from Cuba. The average annual imports of honey during the last 20 years was 140,990 gallons.

The exports of beeswax to all countries for the last 20 years have averaged a little over 100,000 pounds annually. Prior to 1900 this product was consigned principally to the United Kingdom, but during the five years ending with 1914 Canada received nearly as much as all other countries combined. During the five years, 1895–1899, 56.7 per cent of the beeswax exported was sent to the United Kingdom and 1.1 per cent to Canada; 1900–1904, 49.3 per cent was sent to the United Kingdom and 8.7 per cent to Canada; 1905–1909, 49.7 per cent was sent to the United Kingdom and 26 per cent to Canada; 1910–1914, 35 per cent was sent to the United Kingdom and 49.6 per cent to Canada.

Cuba has been the chief source of our beeswax supply during the last 20 years, supplying annually more than any other country and more than all other countries combined for most of that period. The imports in 1895 were 288,001 pounds, of which 180,742 came from Cuba. The imports in 1914 were 1,412,200 pounds, of which 484,989 came from Cuba. The imports from Germany have greatly increased, being 223 pounds in 1895 and 322,578 pounds in 1914.

FEATHERS.

The exports of feathers from this country in 1910 were valued at $312,784 and in 1914 at $640,020. During this period more of this product has been consigned to Canada than to any other country. Other countries receiving large quantities for the same period were Denmark, France, Germany, Italy, and the Netherlands. Beginning with 1895 the annual imports of feathers, crude and undressed, have been valued at more than 1 million dollars. For the five years ending with 1899 the average annual imports were valued at $2,074,745, of which 60.8 per cent came from the United Kingdom. For the five years ending with 1904 the average imports were $2,102,512, of which 69.7 per cent came from the United Kingdom.

For the five years ending with 1909 the average imports were \$3,855,375, of which 58.5 per cent came from the United Kingdom. For the five years ending with 1914 the average imports were \$6,224,799, of which 53.9 per cent came from the United Kingdom. During 1907 and subsequently the imports of feathers, crude, from British South Africa have been valued at more than 1 million dollars annually, amounting to nearly 2½ million dollars in 1913. Ostrich feathers were not separately stated in the import returns until 1912, and since that time 77.2 per cent of the imports of feathers have been ostrich. During the last three years 59.2 per cent of the ostrich feathers came through ports of the United Kingdom and 38.2 per cent from British South Africa.

GLUE AND GELATIN.

Beginning with 1898, and subsequently, the exports of glue have averaged more than 2 million pounds annually, while the imports for the same period ranged from a little over 4 million pounds to nearly 9 million pounds, except in 1914, when the imports amounted to more than 22,700,000 pounds. Since 1895 more than half of the glue exported was consigned to three countries, the United Kingdom, Canada, and Germany, and the same countries, including France, supplied more than three-fourths of the glue imported during the same period.

Imports of gelatin were separately shown in our foreign commerce in 1909. Since that time the average annual imports have been 1,367,635 pounds, of which 53.6 per cent came from Germany. Other countries supplying this product in large quantities were Austria-Hungary, France, Switzerland, and the United Kingdom.

COTTON.

The exports of cotton in 1851 amounted to 927 million pounds, which was increased the following year to more than 1 billion pounds, and doubled in 1881, amounting to more than 2 billion pounds; doubled again in 1905, amounting to more than 4 billion pounds; and amounted to 4,761 million pounds in 1914. As an exporting port for cotton, Galveston exceeded all other ports. That port handled 1,780 million pounds, or 37.4 per cent of all cotton exported, in 1914. New Orleans ranked second, handling 895 million pounds; and Savannah third, amounting to 766 million pounds. This product has been exported chiefly to three countries, the United Kingdom, Germany, and France. The United Kingdom has received approximately one-third of our cotton during the last 20 years, the exports to that country being 1,777 million pounds in 1895 and 1,791 million pounds in 1914. The exports to Germany in 1895 were 752 million pounds, increasing to 1,442 million pounds in 1914. The exports to France in 1895 exceeded 395 million pounds, which increased to 570 million pounds in 1914. Other countries receiving large quantities of cotton during the last five years were Austria-Hungary, Belgium, Italy, Russia, Spain, Canada, Mexico, and Japan. The value of the cotton exported in 1851 was 112 million dollars; in 1866, 281 million dollars; in 1911, 585 million dollars; and in 1914, 611 million dollars, or one-half the value of all products of the farm and forest exported. Imports of cotton came chiefly from Egypt, China, and Peru, some being forwarded by way of Europe. In 1910–1914 the annual imports were nearly 111 million pounds.

GRAIN AND GRAIN PRODUCTS.

The grain and grain products exported in 1851 were valued at $14,556,000. This increased to $160,568,000 in 1874, $269,570,000 in 1881, $334,200,000 in 1898, and decreased to $164,815,000 in 1914. Compared with other agricultural products sent abroad during the last 10 years, grain and grain products held third place, being exceeded by cotton and packing-house products.

The imports of grain and grain products were valued at $1,879,000 in 1851, increased to $10,883,000 in 1856, and again increased to more than $16,000,000 in 1866; decreased to $7,500,000 in 1867, remaining practically at that value until 1891, when the value decreased to $4,567,000, and again decreased to about $2,500,000 for the period 1893–1899. During the last 15 years this product gradually increased from $1,397,000 in 1900 to $27,442,000 in 1914.

Wheat and wheat flour.—For the fiscal years 1911–1914 the value of our exports in wheat and wheat flour, as compared with the total value of our domestic exports, amounted to about 4.1 per cent. During the three fiscal years 1900–1902, inclusive, our exports of wheat, including wheat flour, exceeded 200,000,000 bushels; but such was the decrease in the succeeding years that on an average for the decade 1901–1910 our exports of domestic wheat and wheat flour contributed 7.8 per cent of the total value of our domestic exports. After falling to an average of 4.1 per cent for the last four fiscal years the percentage of our domestic exports formed by wheat and flour rose during the last half of the calendar year 1914 to 18.8, a percentage exactly equal to that for the decade 1871–1880.

Wheat and wheat flour began to make their appearance among our articles of export early in colonial times. It was first sown on the Elizabeth Islands, off the coast of Massachusetts, as early as 1602, and from there was naturally introduced in the various British colonies, where its production increased to such considerable quantities that a surplus was being exported prior to 1723. The first decade for which exports of wheat and flour from the United States can here be given begins with 1791. The total amount exported in the decade was 4,259,285 bushels of wheat and 7,032,865 barrels of flour. Combining the two, on a basis of 5 bushels of wheat to a barrel of flour, we get an annual average for the decade of 3,942,361 bushels of wheat. In the decade 1801–1810 the exports amounted to 3,418,761 bushels of wheat and 9,099,100 barrels of flour, making an annual average of 4,891,426 bushels of wheat, while in the next decade, 1811–1820, the wheat amounted to only 1,026,572 bushels, exclusive of the exports in 1814, and the quantity of flour exported reached a total of 10,199,104 barrels, giving a total of 52,022,092 bushels for the decade, or an average of 5,202,209 bushels yearly.

Out of 142,163,031 bushels of domestic wheat, including flour, exported from the United States between October 1, 1820, and June 30, 1846, the United Kingdom took 23,981,000, or 16.9 per cent, while out of the 51,011,699 bushels exported between July 1, 1846, and June 30, 1849, the United Kingdom received 26,998,000 bushels, or 52.9 per cent. During the long period of practically free trade in breadstuffs covering every fiscal year from July 1, 1849, to June 30, 1914, inclusive, the United Kingdom has taken 53.7 per cent of all the wheat and flour exported from the United States, leaving only 46.3 per cent for all other countries. Only nine times since 1820 have the exports of wheat to France exceeded 10,000,000 bushels, while those for Germany since the German Empire came into existence as such never reached that amount until 1899, for which year the quantity was 10,311,450 bushels, and only seven times in all has the limit of 10,000,000 bushels been exceeded.

Corn.—Doubtless the most striking feature of our corn industry is that the enormous production is absorbed almost entirely by the home demand. Relative to its importance as the greatest of all our grain crops, it is exported in comparatively small amounts. In spite of an increase since 1897 of 25 million acres in the area planted, exports, which in that year attained the maximum of 179 million bushels, have since almost steadily declined, and in 1913 amounted to only 49,064,967 bushels, valued at $28,800,544, while for 1914 there was a tremendous drop of nearly 40 million bushels in our exports of corn, as we exported that year only 9,380,855 bushels, valued at $7,008,028. This drop was probably due to a heavy shortage in the domestic crop, the 1913 yield being only 2,447,000,000 bushels, compared with 3,125,000,000 in the preceding year.

Of all the corn produced in the United States and exported therefrom in the form of grain during the 64 fiscal years from July 1, 1850, to June 30, 1914, no less than 50.3 per cent was exported to the United Kingdom. The total quantity exported during that period of nearly two-thirds of a century was 3,287,804,238 bushels, of which 1,655,241,135 bushels went to the United Kingdom. In recent times the percentage of our exports in corn taken by the United Kingdom has been diminishing, due partly to the increasing competition of other countries in supplying the world's demand for maize and partly to our own increasing use for the corn or produce. Among other countries that have been quite regular purchasers of American corn may be mentioned Germany, British North America, the Netherlands, Denmark, and Belgium.

In general, our imports of corn have been insignificant in amount, but within the last few years increasing quantities have been imported into the United States from Argentina. During the fiscal year 1914 we imported 12,367,000 bushels, of which 11,624,000 bushels were from Argentina. During 1901–1913 the yearly imports of corn ranged from 5,169 to 903,062 bushels.

Rice.—Beginning with 1713, the exports of rice from the British colonies in North America amounted to more than 3 million pounds, and increased to 76,511,000 pounds in 1771, from which an annual decrease is shown to 12,112,000 pounds in 1783, increasing to 50 million pounds in 1789. The exports continued to increase to 105 million pounds in 1828, and 127,789,800 pounds in 1836, then a decrease to 136,143 pounds is shown in 1883, after which a yearly increase is shown to 163,091,000 pounds in 1914.

The imports of rice were nearly 57 million pounds in 1862, which increased 500 per cent in 1914, the imports being 290 million pounds. During the last three years practically all of the "uncleaned" rice has been supplied by Japan. China supplied more than half of the "cleaned" rice during 1912–1913, the imports being 13 and 22 million pounds, respectively. In 1914 more than half of our imports of cleaned rice came by way of the Netherlands, the imports from that country being 48 million pounds, while the imports from China were 30 million pounds. The rice flour, meal, and broken rice imported in 1885 were 38 million pounds, which increased to 140 million pounds in 1914. Germany consigned about 90 per cent of this article 20 years ago, but decreased to a little less than one-half during the last five years, 1910–1914. During this latter period about one-fourth came from the Netherlands, and large quantities also came from Austria-Hungary, the United Kingdom, China, Hongkong, and Siam.

Barley.—Exports of this grain have shown wide fluctuations, the exports being 66,482 bushels in 1864, 9,810 bushels in 1868, nearly 4 million bushels in 1878, 200,000 bushels in 1882, 5 million bushels in 1894, 20 million bushels in 1897, 24 million bushels in 1900, 1½ million bushels in 1912, 18 million bushels in 1913, and nearly 7 million bushels in 1914. The United Kingdom has been the destination for about 75 per cent of our barley during the last 20 years.

The imports of barley during the last 25 years gradually decreased from 11,333,000 bushels in 1890 to 339,000 bushels in 1914. About 90 per cent of the import barley has been supplied by Canada during the last 20 years.

Malt.—The malt exported in 1880 amounted to 5,672 bushels, which increased to 162,000 bushels in 1895, to 453,000 bushels in 1899, to 882,000 bushels in 1906, and decreased to 330,608 bushels in 1914. During the last 10 years Canada and Mexico have been the best markets for malt, receiving about 90 per cent of the malt exported. The imports of malt in 1873 amounted to 279,000 bushels, which increased to 1,356,000 bushels in 1883 and decreased to 5,165 bushels in 1892, and has remained at nearly that figure down to date. European countries, chiefly Germany and the United Kingdom, have supplied practically all of the malt imported during the last 20 years.

Rye.—The exports of rye in 1864 were 154,960 bushels, which increased to more than one-half million bushels in 1868 and increased to 1,564,000 bushels in 1874. During the 10 years 1876–1885 the annual exports were about 2,000,000 bushels, and decreased to 79,000 bushels in 1888, then increased to 12,000,000 bushels in 1892, decreased to 9,000 bushels in 1895, increased to nearly 16,000,000 in 1898, then gradually decreased to less than 3,000 bushels in 1911, and increased to 2,223,000 in 1914. The rye has been consigned chiefly to European countries during the last 20 years, principally Belgium, Germany, the Netherlands, and the United Kingdom.

The imports of rye in 1867 were 242,718 bushels, and remained at nearly that figure until 1878, the imports for that year being 430,235 bushels, which increased to 973,677 bushels in 1883; and since 1886 the imports of rye have been of little importance, decreasing to as low as 5 bushels. As a source of supply Canada has exceeded all other countries, supplying nearly 90 per cent of the rye imported.

Oats.—The exports of oats were 305,755 bushels in 1864; increased gradually to 13 million bushels in 1896; reached 69 million bushels in 1898; decreased to 1 million bushels in 1904; increased to 46 million bushels in 1906; and since that date the exports have been slightly over 1 million bushels, except 1913, when the exports were nearly 34 million bushels. During the 10 years 1894–1903 about 75 per cent of the oats were sent to Belgium, France, the Netherlands, and the United Kingdom. During the five years 1910–1914 the United Kingdom took nearly one-half of the oats, and large quantities were consigned to Cuba and the Philippine Islands.

The imports of oats were about 500,000 bushels during the five years 1851–1855 and ranged from 1 to 10 million bushels during the 10 years 1856–1865. During the five years 1871–1875 the imports were again about 500,000 bushels, decreasing to less than 100,000 bushels during the period 1876–1907. In 1910 the imports were 1 million bushels, valued at $400,000. In 1914 the imports were 22 million bushels, valued at $7,886,000. During the last 20 years about three-fourths of the oats came from Canada.

Buckwheat.—The exports of buckwheat in 1897 amounted to 1,677,000 bushels, valued at $678,959, which gradually decreased to 580 bushels, valued at $695, in 1914. Germany and the Netherlands have received about 90 per cent of the buckwheat since 1897.

Macaroni, vermicelli, etc.—The quantity of macaroni, vermicelli, and similar preparations was not stated prior to 1903, the imports for that year being 28,787,821 pounds, valued at $1,171,887, which increased to 126,128,621 pounds, valued at $5,698,783, in 1914. As a source of supply for this commodity Italy has exceeded all other countries during this period, supplying 94.7 per cent.

Bread and biscuit.—Bread and biscuit have been the principal bakery products consigned to foreign countries and the quantity exported has remained nearly uniform from year to year. In 1866 and subsequently the quantity was stated in pounds and varied from 7,610,400 pounds in 1867 to 17,580,740 pounds in 1884. This article has been sent to nearly all countries on the globe, about half of which went to the British West Indies.

The imports of bread and biscuit were valued at $282,753 in 1912, and $415,318 in 1914. A little more than one-half came from the United Kingdom and about one-third came from three other countries, Germany, the Netherlands, and Japan.

Bran, middlings, and mill feed.—The exports of bran, middlings, and mill feed amounted to 53,548 tons in 1910, 67,687 tons in 1911, 144,504 tons in 1912, 162,321 tons in 1913, and 70,260 tons in 1914. More than three-fourths of this item went to countries in Europe, Germany receiving about two-thirds of the total exports.

Distillers' grains and malt sprouts.—Distillers' and brewers' grains and malt sprouts exported were 59,136 tons in 1901, increased to 102,683 tons in 1906, and decreased to 59,788 tons in 1914. During the last five years nearly one-half has been consigned to Germany, while the greater portion of the remainder went to Belgium and the Netherlands.

Oatmeal.—The oatmeal consigned to foreign countries amounted to 27 million pounds in 1884, decreased to 4 million pounds in 1888, increased to 92 million pounds in 1901, and decreased to 16 million pounds in 1914. During the 10 years 1894–1903 one-half of this article went to the United Kingdom, but shipments to that country decreased to about one-third during the five years 1910–1914. During the latter period the Netherlands received annually from 2 to 8 million pounds and Argentina and the British East Indies each received about half a million pounds annually.

The imports of oatmeal during the seven years 1884–1890 aggregated 1 million pounds annually. During the five years 1891–1895 the annual imports were about half a million pounds and for the 15 years 1896–1909 the annual imports were about 300,000 pounds, increasing to 1 million pounds in 1914. About 90 per cent of this item came from the United Kingdom.

SUGAR.

Beginning with 1901, the annual imports of sugar into the United States have averaged about 4 billion pounds, or nearly ten times the yearly imports in 1851–1855. The great increase occurred in 1866–1870 over the previous five-year period. In 1861–1865 a yearly average of 634 million pounds were imported; in the next five-year period an average of 1,082 million pounds were imported, and again an increase, when in 1876–1880 the average yearly imports equaled 1,670 million pounds. Beginning with 1881–1885, yearly averages exceeded 2 billion pounds, reaching in 1891–1895, 3,744 million pounds; in 1896–1900, 3,900 million pounds; in 1901–1905, 3,721 million pounds; in 1906–1910, 4,006 million pounds; and in 1911–1914, 4,462 million pounds. To the imports subsequent to 1901 should be added the sugar received from Hawaii and Porto Rico, which prior to 1901 were classed as foreign countries. Receipts from Hawaii and Porto Rico during 1911–1914 averaged 1,801 million pounds, which, added to the imports for these years, gives an annual average of 6,263 million pounds. Cuba for more than threescore years has been the chief source of our sugar supply. Imports from Cuba averaged 332 million pounds a year in 1851–1885 and 3,615 million pounds during 1911–1913.

In 1914 the imports from Cuba had risen to 4,926 million pounds, and receipts from Hawaii and Porto Rico were, respectively, 1,114 million and 641 million pounds. Imports from the Dutch East Indies, which in 1906–1910 averaged 610 million pounds a year, decreased to 194 million pounds during 1911–1913.

All but a small fraction of the sugar imported into the United States is intended to be further treated before it is ready for consumption. For convenience this kind of sugar is generally called "raw" sugar and the kind fit for consumption is spoken of as "refined."

Compared with imports, the sugar exported from the United States is relatively unimportant and has been since the beginning of our foreign trade. At present (1914) and for a long period of time the sugar exported is refined. Much of it is sent to Central America and the West Indies, even to countries from which we import raw sugar. Occasionally large quantities are shipped to other countries. In 1911–1913 an average of 26 million pounds a year were sent to the United Kingdom, 30 million pounds to countries in North America, chiefly Central American and West Indian countries, and about 4 million pounds elsewhere. The sugar constituted during 1911–1913 about one-seventh in value of the total imports of agricultural products into the United States.

COFFEE AND COFFEE SUBSTITUTES.

Coffee.—The exports of coffee began in 1901, when the Spanish possessions of Hawaii and Porto Rico became United States territory. The exports of coffee during the fiscal year 1901 were 497,559 pounds, and during the next year the exports increased to more than 27½ million pounds. Exports of this article continued to increase until the latter amount was almost doubled in 1914, the exports being 54 million pounds. The bulk of this coffee is grown and exported from the customs district of Porto Rico, and approximately one-half was taken by Cuba during the period 1901–1914. The bulk of the remainder was sent to four countries, Austria-Hungary, France, Italy, and Spain.

As early as 1790 our coffee imports amounted to more than 4 million pounds. Three years later the imports were over 34 million pounds. More than 103 million pounds were imported in 1835, 236 million pounds in 1856, 516 million pounds in 1883, and more than 1,091 million pounds in 1902, the largest quantity imported for any one year. During the 10 years 1905–1914 the imports averaged 932 million pounds annually. As a coffee importing country compared with other countries, the United States ranks first, the imports for recent years being approximately one-third of the total imports into all countries. As a source of supply, Brazil leads all other countries combined, supplying approximately three-fourths of our coffee during the last 20 years. During the five-year period 1895–1899 the average annual imports of coffee were 735 million pounds, of which 72.5 per cent came from Brazil; 1900–1904 the imports were 929 million pounds annually, of which 78.1 per cent came from Brazil; 1905–1909 the imports were annually 965 million pounds, of which 77.5 per cent came from Brazil; 1910–1914 the imports annually were 899 million pounds, of which 74.8 per cent came from Brazil. Other countries supplying large quantities of coffee during the last five years were Colombia, Mexico, Venezuela, and Guatemala. The imports from each of these countries, except Venezuela, have nearly doubled during the last five years. In 1914 the per capita imports were 10.2 pounds. The consumption of coffee in the United States during the 10 years 1904–1913 averaged annually slightly more than 10 pounds per person. Of the large quantities of coffee imported into the United States through various domestic ports considerably more than one-half entered through the port of New York. Entries through that port for the 10 years 1904–1913 averaged 645 million pounds annually. The port of New Orleans ranked second, with an average of 241 million pounds, and San Francisco third, the entries being 34 million pounds.

Chicory root.—The imports of chicory root during the five years 1910–1914 averaged 2,895,791 pounds annually, of which 81 per cent, or an average of 2,345,263 pounds, came from Belgium and 16.4 per cent, or 474,485 pounds, came from Germany.

Coffee substitutes other than chicory root.—The imports of coffee substitutes other than chicory root in 1910 were 200,008 pounds; in 1911, 169,201 pounds; in 1912, 70,810 pounds; in 1913, 146,897 pounds; and in 1914, 188,446 pounds. More than half of this product came from Germany.

COCOA AND CHOCOLATE.

The yearly imports of crude cocoa and leaves and shells of cocoa was about 2 million pounds from 1851 to 1866; from 1867 to 1879 the average was about 3½ million pounds; increased to 7 million pounds in 1880 and to 176 million pounds in 1914. During the last 20 years about one-half of the cocoa came from countries in North America, chiefly the British West Indies, Cuba, and Santo Domingo. Twenty years ago countries of South America—Brazil, Ecuador, Dutch Guiana, and Venezuela—supplied nearly one-half but decreased to about one-third during the last five years. Also large quantities came through Portugal and the United Kingdom.

The cocoa and chocolate exported in 1902 was valued at $166,000. Five years later this was doubled, amounting to $349,000, which increased to $499,000 in 1911 and decreased to $337,000 in 1914. During the last five years, 1910–1914, Canada received the greater portion of this product. Other important markets during the same period were Panama and Cuba.

Imports of chocolate, including cocoa, prepared or manufactured during the five years ending with 1914 averaged nearly 3 million pounds annually. The Netherlands supplied a little more than one-half, or 51.3 per cent; the United Kingdom, 18.6 per cent; Switzerland, 15.7 per cent; and the greater portion of the remainder came from Germany.

TEA.

Tea has been an important article of our foreign commerce, the imports ranging from 17 million pounds in 1851 to 91 million pounds in 1914. The import value of this product has ranged from 5 million to 17 million dollars for the years 1851 and 1914, respectively.

Compared with other countries in imports of tea, the United States is exceeded by only two countries, the United Kingdom and Russia. The imports into each of the three countries during the calendar year 1913 were 89 million pounds, 306 million pounds, and 152 million pounds, respectively. As a source of supply, approximately 90 per cent of our tea came from China and Japan. During the 10 years, 1895–1904, the imports from China exceeded those from Japan and amounted to about one-half of the imports. During the 10 years, 1905–1914, Japan rose to first place and supplied about one-half of our tea. Other countries consigning large quantities of tea to us were British East Indies, Canada, and the United Kingdom.

The imports of tea waste, siftings, or sweepings, for manufacturing purposes, were a little less than 2 million pounds in 1909, which increased to 6 million pounds in 1914. This product came from the British East Indies and Japan.

TOBACCO.

As early as 1619 the exports of tobacco from the British colonies of North America were 20,000 pounds, valued at $10,950. The exports did not assume large proportions until 1665, when 23,750,000 pounds, valued at $733,875, were exported. With various fluctuations, the exports of this product gradually increased to more than 100 million pounds in 1771, 200 million pounds in 1859, 300 million pounds in 1874, 400 million pounds in 1913, and increased the next year to nearly 450 million pounds, valued at approximately $54,000,000.

During the 10 calendar years, 1903–1912, the United States supplied 41.7 per cent of the world's exports of tobacco, and during the same period 33 per cent of the world's crop of tobacco was produced in this country. For this period the per capita production of tobacco in the United States was 9.3 pounds and the per capita exports were 3.8 pounds. The annual production of tobacco in the United States for the 10 years, 1903–1912, was 824 million pounds, and for the same period 338 million pounds, or 41 per cent, was exported.

During the 10 fiscal years 1903–1912, 68 per cent of the tobacco exports was consigned to four countries—10.5 per cent each to France and Italy, 13 per cent to Germany, and 34 per cent to the United Kingdom. The average annual exports to France for this period were 35,500,000 pounds; to Germany, 43,500,000 pounds; to Italy, 35,900,000 pounds; and to the United Kingdom, 114,100,000 pounds. Other countries to which large consignments were sent in 1914 were the Netherlands, 28 million pounds; Canada, 18 million pounds; Spain, 17 million pounds; Australia, 13 million pounds; Belgium, 12 million pounds; and China, 11 million pounds.

The imports of tobacco were 729,900 pounds in 1847. These imports increased the next year to more than 3 million pounds. Imports continued to show a general increase and reached 21 million pounds in 1890, 40 million pounds in 1907, 68 million pounds in 1913, and fell to 61 million pounds in 1914. Cuba is the source of about one-half of the tobacco imports. Other countries supplying large quantities are Germany, the Netherlands, Asiatic and European Turkey, and the United Kingdom.

OIL CAKE AND OIL-CAKE MEAL AND VEGETABLE OILS.

Oil cake and oil-cake meal.—The exports of oil-cake meals were valued at $739,589 in 1855, which was increased to $21,667,672 in 1914. The quantity increased from 342 million pounds in 1878 to 1,530 million pounds in 1914. This article is a by-product of three grains—corn, cotton seed, and flaxseed.

Imports of oil cake for the last five years ranged from a little more than 5 million pounds in 1910 to 12 million pounds in 1914. This product came chiefly from five countries, Japan supplying nearly one-half. Mexico, the United Kingdom, Canada, and China supplied the remainder.

The exports of corn oil cake were 2,203,000 pounds in 1898, increasing to 59 million pounds in 1914. The cottonseed oil cake exported in 1895 amounted to 490 million pounds, increasing to 800 million pounds in 1914. The flaxseed oil cake increased from 244 million pounds in 1895 to 663 million pounds in 1914. Other oil cake was separately shown in 1912, the exports being 9 million pounds for that year, 7 million pounds for 1913, and 8 million pounds in 1914. France has received about one-half of the corn oil cake, and large quantities have been consigned to Germany, the Netherlands, and Sweden. More than half of the cottonseed oil cake has gone to Denmark and Germany, and large quantities have been consigned to Belgium, France, the Netherlands, Norway, the United Kingdom, and Canada.

Corn oil.—During the five years 1900–1904 about 60 per cent of the corn oil went to Belgium, but shipments to that country decreased to less than one-fourth during the five years 1910–1914. Italy received less than one-tenth of the corn oil in 1900, but received two-thirds in 1914. The shipments of corn oil to all countries were 4,383,926 gallons in 1900, 25,316,799 gallons in 1911, and 18,281,576 gallons in 1914.

Cottonseed oil.—The cottonseed oil exported in 1895 was valued at $6,813,000 and in 1914 at $13,843,000. The Netherlands has been the best market, receiving about one-fourth; also large quantities were consigned to France, Germany, Italy, the United Kingdom, Canada, and Mexico. The exports of this oil amounted to nearly 159 million pounds in 1895, which increased to nearly 400 million pounds in 1912, and decreased to 193 million pounds in 1914.

The imports of cottonseed oil amounted to more than 1½ million gallons in 1912, more than 3 million gallons in 1913, and increased to 17 million gallons in 1914. More than half of this product came from China; other sources of importance were the United Kingdom, Canada, and the Netherlands.

Flaxseed or linseed oil.—Flaxseed oil exported amounted to 62,718 gallons in 1895, increased to 282,188 gallons in 1905, and has fluctuated very little since that date, except in 1913, the quantity being 1,733,925 gallons, of which three-fourths were sent to the United Kingdom.

Flaxseed or linseed oil imported in 1912 was 737,256 gallons; in 1913, 173,690 gallons; in 1914, 192,282 gallons. The chief sources of supply for this item were Germany, the Netherlands, and the United Kingdom. More than one-half came from the Netherlands in 1912, but more than one-half came from the United Kingdom in 1914.

Cocoa butter or butterine.—The cocoa butter or butterine imported in 1910 amounted to more than 3 million pounds, increasing to 6 million pounds in 1912, and decreasing to a little less than 3 million pounds in 1914. The Netherlands, as a forwarding country, was the chief source of supply for this product, and a large quantity also came through Germany.

Coconut oil.—The imports of coconut oil were more than 35½ million pounds in 1907, which doubled seven years later, amounting to 74 million pounds in 1914. About one-half of the coconut oil was supplied by the British East Indies. As a secondary source Belgium, France, and the United Kingdom supplied the greater portion of the remainder, except in 1914, when a large quantity, more than 19 million pounds, came from the Philippine Islands.

Nut oil or oil of nuts.—The imports of nut oil or oil of nuts in 1907 amounted to 2,453,597 gallons, which increased to more than 6 million gallons in 1914. This product was supplied chiefly by France and China. In 1912 this product was stated as Chinese nut and peanut oil. Chinese nut imported in 1912 amounted to 4,767,596 gallons, in 1913, 5,996,666 gallons, and in 1914, 4,932,444 gallons, of which more than 90 per cent came from China. The peanut oil amounted to nearly 900,000 gallons in 1912 and increased to more than 1,300,000 gallons in 1914. The peanut oil came chiefly from France, Germany, and the Netherlands.

Olive oil.—The olive oil imported is of two kinds, one used for manufacturing or mechanical purposes and the other as a salad oil, the salad or table oil being the more important. The salad oil imported in 1906 amounted to nearly 2½ million gallons, which increased to more than 6 million gallons in 1914. About two-thirds of this grade of olive oil came from Italy, that country supplying 1,626,692 gallons in 1906, which increased to 4,319,567 gallons in 1914. Three other countries, France, Greece, and Spain, have each supplied large quantities of this oil. The olive oil used for manufacturing purposes amounted to 2½ million gallons in 1906 and decreased to 763,924 gallons in 1914. During the last five years this product has been supplied chiefly by Italy, Spain, and Turkey in Europe.

Palm oil.—The palm oil imported in 1907 amounted to nearly 30 million pounds, increasing to 93 million pounds in 1910, and decreasing to 58 million pounds in 1914. Practically all of this oil has been forwarded to this country by way of Germany and the United Kingdom, the imports in 1907 being more than 14 million pounds from Germany and 15½ million pounds from the United Kingdom. In 1914 Germany supplied 13 million pounds and the United Kingdom 44 million pounds.

Palm-kernel oil.—The palm-kernel oil imported in 1912 amounted to more than 26 million pounds and in 1913 decreased to 24 million pounds, and increased to 34 million pounds in 1914. About 77 per cent of this product was consigned from Germany, and the greater portion of the remainder came by way of the United Kingdom.

Rapeseed oil.—The rapeseed oil imported during the last three years averaged a little over 1 million gallons annually, valued at $588,138 in 1912 and $704,655 in 1914. More than half of this product came from the United Kingdom. France was next in importance, supplying over 100,000 gallons during each of the three years 1912–1914.

Soya-bean oil.—The imports of soya-bean oil in 1912 amounted to more than 28 million pounds, 12 million pounds for 1913, and 16 million pounds for 1914. About one-half of this product came from Japan. The remainder was supplied by Belgium, the United Kingdom, and China. The import value was $1,577,131 in 1912, $635,888 in 1913, and $830,790 in 1914.

Lemon oil.—The imports of oil of lemon in 1910 amounted to 415,501 pounds, valued at $309,383, which decreased to 385,959 pounds, valued at $858,220, in 1914, of which about 90 per cent was supplied by Italy. The average import price of this oil increased from 74 cents per pound in 1910 to $2.22 per pound in 1914.

NUTS.

The imports of almonds since 1884 have ranged from nearly 4 million pounds in 1884 to 19 million pounds in 1914. This product has been supplied during the last 20 years chiefly by three countries, France, Italy, and Spain.

The coconuts imported since 1905 have been valued at more than 1 million dollars annually. These have been supplied mostly by the British West Indies, those islands supplying approximately 50 per cent.

The coconut meat, broken, or copra, not shredded, desiccated, or prepared, was first separately shown in the customs returns in 1907, when more than 7 million pounds were imported, which more than doubled during the following year and continued to increase to more than 45 million pounds in 1914. This product has been supplied almost entirely by the Philippine Islands and French Oceania.

The imports of coconut meat, broken or copra, shredded, desiccated, or prepared, amounted to more than 5 million pounds in 1912, increasing the following year to nearly 7 million pounds, and to more than 10 million pounds in 1914. This product was supplied almost entirely by the British East Indies.

Cream and Brazil nuts imported in 1907 were 252,538 bushels, which increased to 21,540,000 bushels in 1912, and decreased to 20,423,497 bushels in 1914. This product has been supplied almost entirely by Brazil, that country supplying 233,919 bushels in 1907, 21,454,000 bushels in 1912, and 20,178,535 bushels in 1914.

Filberts imported during 1910–1914 averaged about 12 million pounds annually. About 10 million pounds, or nearly 90 per cent, came from Italy. Two other countries supplying the principal portion of the remainder were Spain and Turkey in Asia.

The exports of peanuts, which were a little over 7 million pounds in 1906, increased to slightly more than 8 million pounds in 1914. Canada received about three-fourths of this article, and other countries receiving large quantities were the United Kingdom, the Netherlands, the Central American States, and Guiana.

The imports of peanuts during the last five years ranged from 29 million pounds in 1910 to more than 44 million pounds in 1914. Four countries were the chief sources of supply for this product, France, Spain, China, and Japan. Nearly one-half of this product has been supplied by Japan.

The imports of walnuts in 1903 amounted to more than 12 million pounds, increasing to 37 million pounds in 1914. About two-thirds of these were supplied by France. Two other countries, Italy and China, each supplied large quantities. The imports were valued at $1,106,000 in 1903, which increased to $4,339,000 in 1914.

ALCOHOLIC LIQUORS.

Distilled spirits.—The exports of alcohol, including cologne spirits, during the 10 years 1905–1914 ranged from 1,081,871 proof gallons in 1905 to 187,845 proof gallons in 1914. Canada has been the best market for this product, receiving about one-half of the total exports.

The annual imports of brandy during the last 30 years was approximately 500,000 proof gallons, the range being from 138,000 gallons in 1898 to 716,000 gallons in 1910. France has supplied considerably more than all the other countries combined. In 1903 and subsequently the import value of this article aggregated $1,000,000 annually.

The imports of cordials, liqueurs, etc., were 532,151 proof gallons, valued at $1,059,929, in 1912; and 515,575 gallons, valued at $1,063,-267, in 1914.

Since 1910 the annual average quantity of gin imported has been about 1 million gallons, of which about 95 per cent has been supplied by the Netherlands and the United Kingdom, the import value being slightly less than $1 per gallon.

The exports of rum ranged from 865,275 proof gallons in 1886 to 1,388,738 gallons in 1914. During the 10 years 1905–1914 the exports of this product have averaged more than 1,000,000 proof gallons, valued at an average price of a little more than $1 per gallon.

The annual imports of whisky since 1910 have been a little over 1 million gallons, of which nearly three-fourths was supplied by the United Kingdom. Canada was the next country in importance and supplied nearly 375,000 gallons annually.

The bourbon whisky exported 30 years ago, or in 1885, amounted to 4,794,646 proof gallons. With one exception, 1894, when the exports amounted to 4,105,639 gallons, this product has shown a general decline to 47,775 gallons in 1914. During the 15 years 1895–1909 Germany was our best customer, taking a little more than 73 per cent of this product.

The exports of rye whisky decreased from 834,087 proof gallons in 1884 to 134,152 proof gallons in 1914. Germany, the Philippine Islands, and the Central American States have been the best markets for this product.

Malt liquors.—The exports of malt liquors were valued at $558,770 in 1895, increased to slightly more than $2,000,000 in 1900, and decreased to $1,485,000 in 1914. The malt liquors in bottles have been consigned chiefly to the West Indies, Central American States, Hawaii, and the Philippine Islands.

The malt liquors imported during the last 25 years have ranged from a little over 3 million gallons in 1891 to more than 7 million gallons in 1914. Three countries, Germany, the United Kingdom, and Austria-Hungary, have supplied practically all of the malt liquors imported during this period.

Wines.—Our export wine trade did not develop until near the close of the Civil War. The exports in 1864 were valued at $84,000, which increased to $118,110 in 1886; $729,000 in 1898; and decreased gradually to $373,412 in 1914. This article has been consigned chiefly to Germany, the United Kingdom, Canada, Mexico, and Japan.

Champagne and other sparkling wines imported since 1884 have averaged a little less than 300,000 gallons annually, the imports in 1884 being 201,000 gallons, increasing to 270,000 gallons in 1914. Practically all of this product came from France.

The still wines imported since 1851 have varied from nearly 6 million gallons in 1851 to a little over 7 million gallons in 1914. The smallest quantity imported for any one year during that period was slightly less than 2¾ million gallons in 1898, and the largest quantity imported was 11 million gallons during 1866. For the last five years about one-half of this product has been supplied by Italy.

SEEDS.

Castor beans.—Castor beans imported during the last five years ranged from 726,002 bushels in 1910 to 1,030,543 in 1914. Practically all of this commodity was supplied by the British East Indies and the United Kingdom, the import value being a little over $1 per bushel.

Clover seed.—European countries have received practically all of our clover seed, amounting to 22,901,000 pounds in 1895 and 4,641,000 pounds in 1914. During the 10 years 1895–1904 a little less than half was sent to the United Kingdom, with Germany as the next best customer. During the five years 1910–1914, Germany, the United Kingdom, and Canada received the greater portion. About two-thirds went to Canada during 1913–14.

Canada, France, Germany, Italy, and the United Kingdom have supplied about 90 per cent of the clover seed imported during the last eight years. France and Germany have supplied nearly one-half, the quantity from each being nearly equal. During each of the years 1913 and 1914 a little over 6 million pounds of red-clover seed were imported, while other clover seed amounted to 15 and 23 million pounds, respectively.

Cotton seed.—As a destination for cotton seed, the United Kingdom exceeded all other countries during the 10 years 1895–1904, taking about 90 per cent, the range being from 9 to 46 million pounds. During the five years 1905–1909, the consignments were about evenly divided between Germany, the Netherlands, and the United Kingdom, each receiving about 6 million pounds annually. During the five years 1910–1914 about three-fourths was sent to Germany. Mexico has also been a good market, receiving a yearly average of about 2 million pounds during the last 17 years.

Flaxseed.—The countries of northern Europe have been the chief markets for our flaxseed, taking about 90 per cent during the last 20 years. The countries of this group were Belgium, Germany, the Netherlands, and the United Kingdom. The yearly average of flaxseed sent abroad during 1895–1904 was about 2 million bushels. During the five years 1910–1914 the yearly average decreased to 78,586 bushels.

The flaxseed imported in 1910 amounted to 5 million bushels, 10 million bushels in 1911, 7 million bushels in 1912, 5 million bushels in 1913, and nearly 9 million bushels in 1914. During 1910–11 one-half of this product came from Argentina; but Canada supplied two-thirds during 1912–13 and practically all in 1914. During the five years 1910–1914 the average import price of flaxseed was $1.70 per bushel.

Sugar-beet seed.—Sugar-beet seed shown in our imports in 1910 amounted to 10 million pounds, 11 million pounds each for 1911 and 1912, 15 million pounds in 1913, and 10 million pounds in 1914. Approximately 90 per cent of this product came from Germany. The import value of this seed was $668,000 in 1910, $1,103,000 in 1912, and $800,000 in 1914.

Timothy.—The timothy seed sold to foreign countries during the last 25 years had a yearly average of about 13 million pounds, with very slight fluctuations from year to year. European and North American countries took more than 95 per cent, each taking about the same amount. The principal customers in Europe were Germany and the United Kingdom, while Canada was the best market on the western continent.

SPICES.

The exports of spices from the United States in 1884 were valued at $41,191, which increased to $84,427 in 1914. About one-third of this product during the five years 1910–1914 went to Canada, Mexico, and the Philippine Islands.

The imports of all kinds of spices were valued at $780,650 in 1851 and $5,595,509 in 1914. These came chiefly from British and Dutch East Indies, but other sources of importance were the Netherlands, the United Kingdom, and the British West Indies.

The imports of cassia and cassia vera in 1912 were 6,795,943 pounds; in 1913, 6,853,915 pounds; in 1914, 6,771,901 pounds. The value of this product was $514,758 in 1912, $535,974 in 1913, and $404,853 in 1914. About one-half came from China and the remainder came chiefly from three countries—Hongkong, the Dutch East Indies, and the Netherlands.

The ginger root, not preserved, imported in 1912, amounted to 5,979,314 pounds, 7,756,090 pounds in 1913, and 3,771,086 pounds in 1914. The value was $368,175 in 1912, $399,270 in 1913, and $171,250 in 1914. The United Kingdom supplied one-half of this item, and nearly all of the remainder came from Jamaica, China, British India, Hongkong, and Japan.

The black and white pepper imported in 1884 aggregated 13 million pounds, which was nearly doubled in 1914, amounting to more than 24 million pounds.

The imports of ginger, preserved or pickled, in 1899 amounted to 142,698 pounds, valued at $6,309. This quantity increased to 478,058 pounds, valued at $36,434, in 1914. Practically all of this product has been supplied by China and Hongkong.

VEGETABLES.

Beans and peas exported in 1900 amounted to 617,355 bushels, which decreased to about one-half in 1914, the exports being 314,655 bushels. In 1900 the export value of this product was about $1.60 per bushel, which increased to about $2.75 per bushel in 1914. As a destination for our beans and peas Cuba has led all other countries during the last 20 years, receiving approximately one-half of the total exports.

During the last five years the imports of beans have averaged more than 1 million bushels annually, valued on an average of a little over $1.75 per bushel. These have been supplied by Austria-Hungary, France, Italy, Mexico, and Japan.

The exports of onions have ranged from 53,335 bushels in 1895 to 386,322 bushels in 1914. The average annual exports for the 10 years 1895–1904 were about 100,000 bushels. During the five years 1910–1914 this quantity was increased to about 350,000 bushels annually. Canada has been the chief market during the last five years, receiving from 100,000 to 300,000 bushels annually. Other countries to which large quantities were consigned were Panama, Mexico, and Cuba.

The onions imported in 1897 amounted to more than 560,000 bushels, which increased to a little over 1 million bushels in 1914. This product came chiefly from Spain, the United Kingdom, and Bermuda. Large quantities also came from the Canary Islands and Egypt.

During the last three years the imports of dried peas were supplied chiefly by Germany, Canada, and Mexico. The imports amounted to 806,762 bushels in 1912, 1,134,346 bushels in 1913, and 866,488 bushels in 1914. The average import price has been a little less than $2 per bushel.

The exports of potatoes in 1851 were slightly more than 106,000 bushels, which increased to more than 500,000 bushels in 1863, and remained at practically that figure until 1893, when the quantity exceeded 845,000 bushels. This quantity increased to 999,476 bushels in 1910, and during the four years 1911–1914 the average exports were nearly 2 million bushels annually. During the last five years the average export value per bushel was slightly less than $1. During the 20 years 1895–1914 Cuba has been our best market for potatoes, receiving approximately one-half of the total supply exported.

The imports of potatoes have been supplied chiefly by Bermuda and Canada with a small quantity from Mexico. The imports were 299,000 bushels in 1851 and 3,646,000 in 1914. In 1914 Belgium supplied 1,168,220 bushels, Denmark 384,662 bushels, the Netherlands 803,144 bushels, and Canada 1,025,536 bushels. The average import price of potatoes during the five years 1910–1914 was 53 cents per bushel.

The United Kingdom, Canada, Panama, Mexico, and the Philippine Islands have been our best customers for canned vegetables. The value of this product consigned to the United Kingdom ranged from a little more than $160,000 in 1910 to $376,000 in 1914. The total value of this product exported in 1910 was $783,000, which increased to $1,521,000 in 1914.

The imports of mushrooms and truffles were more than 7 million pounds in 1910, which increased to 9 million pounds in 1914. Practically all of this product came from France, that country supplying more than 6 million pounds in 1910 and 8 million pounds in 1914. Imports from Japan amounted to more than half a million pounds during the five years 1910–1914.

The pickles and sauces exported during 1913 were valued at $837,571; in 1914 the value was $928,611. About one-half of this product was consigned to the United Kingdom. Canada, Cuba, the Philippine Islands, and Panama were also good customers.

The pickles and sauces imported in 1860 were valued at $137,000. Twenty years later the imports of this product were valued at $295,000, which increased to $1,246,000 in 1914. During the last five years this article has been supplied by three countries, Italy, the United Kingdom, and Japan, each supplying approximately one-third of the total imports.

FRUITS.

In viewing the situation of this country as to exports and imports of fruit, the years 1903 and 1913 are used for comparison.

In the year 1903 the imports of oranges were valued at $818,780, as against $233,760 in 1913. But meanwhile the orange groves in this country had been growing, both in age and extent, for in 1913 the exports were valued at $2,976,520, while the exports for 1903 were only $465,397. In 1903 the oranges received from the British West Indies amounted to $495,256, which decreased to $62,618 in 1913. In 1903 imports from Italy were valued at $197,620, but decreased in 1913 to $70,651.

Imports of figs from Turkey in Asia were 11,642,204 pounds in 1903, compared with 13,981,643 pounds in 1913. From Greece we received 1,940,793 pounds of figs in 1903 and 1,517,901 pounds in 1913, and from Spain we received 275,531 pounds of figs in 1903, which decreased in 1913 to only 74,852 pounds. But, despite these decreases in importations of fruit from some individual countries, the total imports for each of the two years remain about 16½ million pounds.

Of prunes we exported in 1903, 66,385,215 pounds; in 1913, 117,950,875 pounds. Of this amount in 1903 about 4½ million went to Belgium, 18½ million to Germany, 16 million to France, and 15 million to the United Kingdom. In 1913 about 6 million pounds went to Belgium, 49 million to Germany, 12 million to France, and 8½ million to the United Kingdom. Imports of prunes amounted to 673,516 pounds in 1903 and decreased to 266,661 pounds in 1913. These came chiefly from Austria-Hungary, France, Germany, and Japan.

Our imports of fresh apples are comparatively small compared with exports, for in 1913 imports amounted to 7,559 barrels, while our exports for the same year were 2,150,132 barrels. In 1903 the exports were over 1½ million barrels, making a gain of nearly 1 million barrels in our exports in 10 years. The United Kingdom received the greater part of our apples, while large shipments were consigned to Germany, Canada, and Mexico. Fresh apples from this country find their way to almost every country on the globe. Even Siam received 2 barrels in 1913.

The dried apples exported in 1903 were 39,646,297 pounds; in 1913, 41,574,562 pounds, while our imports for 1903 were 3,098 pounds and in 1913, 7,072 pounds, which shows conclusively that we are able to raise all the apples required for consumption in this country besides having many for export.

No dried apricots are imported, but an increase of nearly 400 per cent is shown in our exports of this fruit since 1903, the exports for that year being about 9 million pounds and 35 million pounds for 1913. Belgium, France, Germany, the United Kingdom, the Netherlands, and Canada were all large purchasers of apricots. The exports to Germany increased from about 2½ million pounds in 1903 to over 7½ million pounds in 1913.

In 1903 the imports of raisins exceeded the exports, the imports being 6,700,000 pounds and the exports 4 million pounds. But that relation was changed in 1913, when the imports were 2,580,000 pounds and the exports 28 million pounds. Our exports to Canada increased from 3,141,258 pounds in 1903 to over 18 million pounds in 1913. The imports of raisins from Greece fell in the 10 years from 261,802 pounds in 1903 to 27,543 pounds in 1913; from Italy, from 7,872 pounds in 1903 to 161 pounds in 1913, and from Spain and Turkey in Asia the decrease was about 2 million pounds each.

Imports of currants in 1903 were 33,878,209 pounds, and 30,843,735 pounds in 1913, of which more than 98 per cent came from Greece, with small amounts from Italy, Spain, and the United Kingdom. Currants are really the Corinth raisin, so called because of their origin in the Levant, some of which are grown in this country.

Imports of dates in 1903 were nearly 22 million pounds, in 1913 over 34 million pounds, of which the largest amount came from Turkey in Asia, nearly 15 million pounds in 1903, and over 27 million pounds in 1913.

Imports of bananas were valued at 8½ million dollars in 1903, and 14½ million dollars in 1913. We get the most of our bananas from Central America, Cuba, and the British West Indies, having received from the British West Indies alone in each of the years 1903 and 1913 about 3½ million dollars worth. The value of our banana trade with Cuba increased from $670,690 in 1903 to $834,206 in 1913, and for Colombia, from $612,114 in 1903 to $1,107,429 in 1913.

In 1903 the imports of lemons were 152 million pounds, valued at over 3 million dollars; in 1913 the imports were 151 million pounds, valued at 4 million dollars, of which more than 95 per cent came from Italy.

The imports of pineapples in 1903 were valued at $634,945, and $1,319,006 in 1913. Most of them came from Cuba, but a small quantity came from the Straits Settlements, the Azores and Madeira Islands, and Mexico.

More than 97 per cent of the grapes came from Spain during the five years 1909–1913, amounting to 1½ million cubic feet capacity of from 25 to 30 pounds annually at an average value of about $1 per cubic foot. Belgium, Canada, and the Netherlands each supplied small quantities.

The exports of dried peaches were first separately stated in 1906 and amounted to 1,182,000 pounds, which increased to 7 million pounds in 1911 and decreased to 6½ million pounds in 1913. Germany received 211,355 pounds in 1906 and 2,432,000 pounds in 1913. Canada took 479,431 pounds in 1906 and 2,365,000 pounds in 1913.

Our export trade in fresh pears was valued at $631,972 in 1906 and increased slightly to $796,913 in 1913, Canada, the United Kingdom, Cuba, and Brazil being the largest purchasers; a little less than one-third went to Canada and more than one-half went to the United Kingdom. Hongkong and the Philippines were the smallest purchasers, Hongkong taking $25 worth and the Philippines $24 worth.

VEGETABLE FIBERS.

Flax.—The imports of flax fiber in 1895 were 7,233 tons, and in 1914, 9,885 tons. During the last five years about 90 per cent of this product was supplied by European countries, chiefly Belgium, Russia, and the United Kingdom.

Hemp.—Like flax, our supply of hemp has come chiefly from European countries, mostly from Italy, during the last 20 years. The imports were 6,954 tons in 1895 and 8,822 tons in 1914. From 1870 to 1890 the imports were larger, ranging from 22,557 tons in 1870 to 36,591 tons in 1890. The average annual value for 1907 and subsequently has been more than $1,000,000.

Istle or Tampico fiber.—Imports of istle or Tampico fiber (used for bagging, carpets, hammocks, etc.) increased from 2,956 tons in 1885 to 15,607 tons in 1905, and decreased to 10,660 tons in 1914. Practically all of this fiber has been supplied by Mexico. The import value in 1900 was $475,090, or $83 per ton; in 1914 the value was $1,036,431, or $97 per ton.

Jute and jute butts.—The quantity of imports of jute and jute butts (used for making carpets, bags, etc.) has remained practically the same for the last 30 years. The imports in 1885 were 98,343 tons and 106,033 tons in 1914, with slight fluctuations for intervening years, the range being from 50,037 tons in 1894 to 141,704 tons in 1891. The value, however, has shown a large increase, from 3 million dollars in 1885 to 11 million dollars in 1914, this being due to an increase in the import price per ton of from $31 to $105. Practically all of this article has been supplied by British India.

Kapoc.—The imports of kapoc fiber (a substitute for cotton) in 1911 amounted to 2,070 tons; in 1914, 1,827 tons. The Dutch East Indies supplied 84 per cent of this commodity, but a small quantity came from British India, Ecuador, and the Netherlands.

Manila.—The manila fiber imported has been supplied almost exclusively by the Philippine Islands. The imports of this product amounted to 35,331 tons, valued at $6,218,254, or $176 per ton, in 1891; increased to 93,253 tons, valued at $10,517,100, or $113 per ton, in 1910, the largest quantity imported for any one year; and decreased to 49,688 tons, valued at $9,779,539, or $197 per ton, in 1914.

New Zealand flax.—The imports of New Zealand flax were first shown in our import trade in 1910, and since that time two-thirds of it came directly from New Zealand, the country from which it takes its name. The quantity imported in 1910 was 3,353 tons, valued at $362,888; in 1914, 6,171 tons, valued at $716,953.

Sisal grass.—Imports of sisal grass (largely used for binder twine) have quadrupled in the last 20 years, the imports in 1895 being 47,596 tons and 215,547 tons in 1914. The average value per ton has doubled, being $58 in 1895 and $120 in 1914. This product has been supplied almost exclusively by Mexico, chiefly the State of Yucatan. The imports from that country in 1895 were 47,483 tons, valued at $2,734,909, and 195,086 tons, valued at $25,980,480, in 1914.

MINOR AGRICULTURAL PRODUCTS.

The argols or wine lees (crude cream of tartar) imported were 32,115,646 pounds in 1909 and 29,793,011 pounds in 1914, of which nearly 90 per cent came from France and Italy.

The exports of glucose or grape sugar were 229 million pounds in 1899 and 200 million pounds in 1914, of which about 80 per cent went to the United Kingdom since 1908.

The exports of ginseng were 106,510 pounds in 1851, which increased to 224,605 pounds in 1914. During the last 20 years Hongkong has taken about 95 per cent, and the export value during the last five years has averaged $7.54 per pound.

The exports of hay were 153,431 tons in 1902 and 50,151 tons in 1914. The imports were 48,415 tons in 1902 and 170,786 tons in 1914. The United Kingdom was the destination of about one-third of the exports and Canada supplied practically all of the imports.

As an exporting country for hops this country is exceeded by Austria-Hungary and Germany, and is exceeded in imports by Belgium and the United Kingdom. The exports increased from 650 pounds in 1791 to 24,262,896 pounds in 1914, and the imports increased from nearly 500,000 pounds in 1881 to 5 million pounds in 1914. The United Kingdom took most of the exports and Austria-Hungary and Germany supplied nearly all of the imports.

Nearly all of the indigo came from Germany and increased from 1 million pounds in 1851 to 8 million pounds in 1914. The imports of licorice root were 115,636,131 pounds in 1914, of which about 70 per cent came from Russia and Turkey. The exports of nursery stock were valued at $315,065 in 1914 and the imports were valued at $3,606,808. The exports went to Canada and the imports came from the Netherlands. The annual imports of opium since 1870 have been about 500,000 pounds, 75 per cent came from Turkey and 15 per cent came through the United Kingdom. The sago, tapioca, etc., was valued at $1,641,540 in 1914, and came chiefly from British and Dutch East Indies. The vanilla beans came from French Oceania and Mexico, and amounted to 898,100 pounds in 1914.

Nearly all of the exports of broom corn were consigned to Canada, while Austria-Hungary and Italy supplied nearly all of the imports. Imports of curry and curry powder came from the United Kingdom, and were valued at $11,861 in 1914. The exports of flavoring extracts and fruit juices amounted to $85,000 in 1910 and $107,000 in

1914. The exports of natural flowers were valued at $121,000 in 1914 and the imports at $24,540. The malt extract, fluid or solid, came chiefly from the United Kingdom and was valued at $16,566 in 1914. The exports of roots, herbs, and barks were valued at $531,071 in 1914. The exports of starch were 76,714,000 pounds in 1914 and the imports were 15,518,000 pounds. The exports of straw were valued at $4,714 in 1914 and the imports were valued at $33,499.

The exports of molasses were 1,002,441 gallons in 1914 and the imports were 51,410,271 gallons. The sirup exported in 1914 was 11,631,000 gallons. Teazels came from France and were valued at $24,310 in 1914. There were 125,666 gallons of vinegar exported in 1914 and 311,643 gallons imported. One-half of the unmedicated wafers came from Germany and were valued at $32,797 in 1914. The imports of vegetable wax in 1914 were 4,255,686 pounds, and the exports of yeast in 1914 were valued at $332,895.

LOGS, LUMBER, AND TIMBER.

During the last half century the exports of timber may be divided conveniently into four periods that show the development of the trade, each period doubling over the preceding one. During the first period, 1865–1869, the value of the yearly exports were $1,451,607; during the second period, 1870–1881, the value was $3,794,097; during the third period, 1882–1899, the value was $6,131,414; and during the fourth period, 1900–1914, the value was $12,412,688.

The exports of logs and round timber were 138,067,000 feet in 1914 and the imports were 148,938,000 feet. The exports went to Germany, the United Kingdom, Canada, and the Netherlands, and the imports came chiefly from Canada.

Our export trade in lumber consists of boards, deals, planks, laths, shingles, shooks, etc., and was consigned chiefly to the United Kingdom, the Netherlands, Germany, Canada, Mexico, the West Indies, Argentina, and Brazil, while Canada was the chief source of supply for imports. In 1895 the exports were valued at $14,959,287 and the imports at $7,259,428. In 1914 the value of the exports was $72,484,756 and the imports $22,436,585. The boards, deals, planks, and other sawed lumber exported in 1914 were valued at $57,574,548 and the imports at $17,817,550. The joists and scantling exported in 1914 were 12,143,000 feet, valued at $206,919, of which about two-thirds went to Canada and Panama.

The imports of laths were 564,778,000, valued at $1,613,586, in 1914, of which more than 99 per cent came from Canada. The number of railroad ties exported were 5,416,713, valued at $2,616,563, in 1913, and 5,123,004, valued at $2,564,543, in 1914, of which about three-fourths went to Canada. The exports of shingles were

46,964,000, valued at $112,463, in 1914, and the imports were 895,038,000, valued at $2,190,170. Canada received more than 72 per cent of the exports and was the source of about 98 per cent of the imports. The exports of shooks in 1914 were 12,017,337, valued at $2,812,749. These were sent chiefly to Cuba, Mexico, the Straits Settlements, Argentina, and China.

The exports of staves and heading increased from $3,138,424 in 1895 to $6,184,892 in 1914. These were consigned chiefly to countries of northwestern Europe, Canada, and the West Indies. Other lumber exported in 1914 was valued at $3,028,642 and the imports of a similar class were valued at $815,279. The briar root imported during the last five years had an average value of a little more than $300,000, which came chiefly from France, Italy, and French Africa. The cedar imported amounted to 17,285,000 feet, valued at $982,152, in 1914, of which more than half came from Cuba. The mahogany imported amounted to 70,470,000 feet, valued at $4,925,126, in 1914. During the last 10 years about one-half of the mahogany imported came from the United Kingdom and Mexico. Imports of other cabinet woods were valued at $721,000 in 1910 and increased to $1,217,000 in 1914. The imports of chair cane or reed were valued at $451,099 in 1914, of which about 90 per cent came from Germany.

The imports of pulp wood in 1914 were 1,073,023 cords, valued at $7,245,466, all of which came from Canada. The rattans and reeds were supplied by the Straits Settlements and large quantities came through Germany, the total imports being valued at $885,000 in 1910 and $1,210,000 in 1914.

NAVAL STORES.

The rosin exported from the United States constitutes about two-thirds of the world's trade in that product and amounted to 2,417,950 barrels, valued at $11,217,316, in 1914. For a number of years Germany and the United Kingdom have taken about one-half of this article. The exports of tar, turpentine, and pitch in 1914 were 351,353 barrels, valued at $568,891, of which about 90 per cent went to France and Italy. Compared with other countries, the United States ranks first in the world's trade in spirits of turpentine, exporting about three-fourths of the world's supply. The exports in 1914 were 18,900,704 gallons, valued at $8,095,958. The imports of naval stores are small quantities of tar and pitch of wood and spirits of turpentine, the total value in 1914 being $36,764.

GUMS.

The imports of india rubber in 1910 were 101,044,681 pounds, valued at $101,078,825; in 1914, 131,995,742 pounds, valued at $71,-219,851, of which Brazil and the United Kingdom each supplied about one-third in 1914. The import value per pound decreased from slightly more than $1 in 1910 to 54 cents in 1914. Compared with other countries, this country exceeds all others in imports of this article. The balata rubber gum imported in 1910 amounted to 399,000 pounds and increased to 1,533,024 pounds in 1914, nearly all of which came from Guiana and Venezuela. The guayule gum came from Mexico, and amounted to 19,749,522 pounds in 1911 and 1,475,804 pounds in 1914. The gutta-joolatong or East India gum came from the Straits Settlements, and amounted to 24,926,571 pounds, valued at $1,155,402, in 1914. The gutta-percha also came from the Straits Settlements, and amounted to 1,846,109 pounds, valued at $323,567, in 1914.

The camphor gum was supplied by Japan, and is of two kinds—crude and refined. In 1914 the imports of crude were 3,476,908 pounds, valued at $929,715, and the refined amounted to 566,106 pounds, valued at $182,790. The chicle gum (used largely for the manufacture of chewing gum) came from British Honduras, Mexico, and by way of Canada, and amounted to 8,040,891 pounds, valued at $3,012,458, in 1914. The chicle gum brought from Canada is a Honduran and Mexican product sent there to dry, as it dries best in a cold country. The drying process reduces the weight about one-half, which makes a saving in the duty. It is on the free list in Canada, but is dutiable in this country at 15 cents per pound in the crude state and 20 cents per pound dried or manufactured. The imports of copal, kauri, and damar gum amounted to 32,693,412 pounds, valued at $3,354,679, in 1914. The gambier or terra japonica gum came from the Straits Settlements and amounted to 14,936,129 pounds, valued at $571,067, in 1914. The gum shellac came from British India and amounted to 16,719,756 pounds, valued at $2,689,269, in 1914.

MINOR FOREST PRODUCTS.

In 1914 the exports of wood pulp were 26,961,254 pounds, valued at $529,741, and the imports were 1,138,727,195 pounds, valued at $17,023,338. The imports came from Canada and the exports went to Europe, yet those countries were the source of much more than they received. In 1914 the exports of tanning materials were valued at $666,880, while the imports were valued at $4,368,041. The dyewoods and extracts imported were valued at $793,926 in 1914. In 1914 the value of the charcoal exported was $81,997, and the import value was $60,634. About 99 per cent of the cinchona bark (from which quinine is extracted) came through the Netherlands and amounted to 3,648,868 pounds, valued at $464,412, in 1914. The cork wood or cork bark imported in 1851 was valued at a little less than

$20,000, which increased to nearly $4,000,000 in 1914. Portugal and Spain have supplied about 85 per cent since 1910. The vegetable ivory or tagua nuts came from Colombia, Ecuador, and Panama and amounted to 27,135,406 pounds, valued at $881,354, in 1914.

The imports of natural palm leaf were valued at $14,044 in 1914, and the exports of moss were valued at $51,006. The exports of wood alcohol in 1914 were 1,598,776 gallons, valued at $652,486, of which 90 per cent went to the United Kingdom, the Netherlands, and Germany.

REEXPORTS.

"Foreign exports," or reexports, comprise those articles of foreign origin imported into this country which are subsequently exported without change in their form.

Farm products.—During the 14-year period from June 30, 1901, to June 30, 1914, reexports of farm products averaged 12½ million dollars yearly, ranging from 9½ millions in 1909 to 17¾ millions in 1914. In percentage they represent 43 per cent of total foreign exports, 2.1 per cent of total agricultural imports, and 1.3 per cent of domestic agricultural exports.

Coffee, tobacco, hides and skins, and bananas, named in the order of their importance, were the chief articles of reexport for the period named, each averaging over 1 million dollars a year. Coffee averaged 20,675,000 pounds annually, valued at $1,854,000; tobacco, 2,790,000 pounds, valued at $1,413,000; hides and skins, 6,334,000 pounds, valued at $1,333,000; and bananas, $1,280,000. The quantity of bananas is not given prior to 1908.

In 1914 bananas held first place, followed by tobacco, hides and skins, and coffee. Reexports of bananas amounted to 2,255,000 bunches, valued at $2,437,000; tobacco, 2,621,000 pounds, valued at $1,538,000; hides and skins, 6,426,000 pounds, valued at $1,408,000.

Forest products.—Exports of foreign forest products for the 14 years averaged 5¼ million dollars annually. They were lowest in 1903, at $2,865,000, and highest in 1910, when they reached $9,802,000. In percentage they amounted to 17.8 per cent of the total foreign exports, 4.5 per cent of the total forest products imported, and 4.7 per cent of domestic forest products exported.

India rubber was the chief article of reexport for the 14-year period, averaging 4,262,000 pounds annually, valued at $3,559,000, and ranging from 2,912,000 pounds in 1903 to 6,493,000 pounds in 1910.

Chicle, the basis of chewing gum, was next in importance, reexports averaging 1,875,000 pounds, valued at $481,000. There were violent fluctuations in the reexports of this product. Thus the year in which exports were lowest, 586,000 pounds, immediately preceded the high record year of 1913, when 4,897,000 pounds were exported.

Lumber, including boards, planks, deals, and other sawed lumber, ranked third in importance, averaging 16,811,000 feet, valued at $345,000. There has been a marked decrease in the last three years.

TRANSPORTATION.

Exports of domestic merchandise for the 14 years 1901–1914 averaged 1,774 million dollars yearly, 88.5 per cent of which was carried in vessels and 11.5 per cent in cars and other land vehicles. Of the domestic exports shipped in vessels, averaging 1,570 million dollars annually, steamships carried 97.2 per cent and sailing vessels 2.8 per cent. American steamships carried 7.3 per cent and foreign 89.9 per cent. American sailing vessels carried 0.6 per cent and foreign 2.2 per cent. American steamships carried 4.8 per cent of this trade in 1901, 9.2 per cent in 1906, and 7.8 per cent in 1914.

There has been a general downward trend in the proportion of sea-borne domestic exports carried by sailing ships, ranging in the case of American ships from 1.2 per cent in 1901 to 0.34 per cent in 1912, and in the case of foreign ships from 4.9 per cent in 1902 to slightly less than 1 per cent in 1914.

Total imports for the 14 fiscal years 1901–1914 average 1,319 million dollars yearly, 93.5 per cent of which came in vessels and 6.5 per cent in cars and other land vehicles. Of the imports arriving by sea, averaging 1,234 million dollars annually, steamships brought 98.1 per cent and sailing ships 1.9 per cent. American steamships carried 11.5 per cent and foreign 86.6 per cent; American sailing vessels carried 0.7 per cent and foreign 1.2 per cent. The proportion brought by American steamships was highest in 1905, amounting to 14.6 per cent, and lowest in 1910, amounting to 9.6 per cent.

The sailing ship has steadily diminished in importance as a carrier in the import trade. Thus the percentage of sea-borne imports arriving in American sailing ships fell from 1.9 per cent in 1901 to 0.32 per cent in 1914, while the proportion carried in foreign sailing ships in 1914 amounted to just one-tenth of the 2.8 per cent carried in 1903.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATING TO AGRICULTURAL EXPORTS AND IMPORTS.

Bureau of Statistics bulletins:

- No. 29. Methods and routes for exporting farm products.
- No. 38. Crop-export movement and port facilities on the Atlantic and Gulf coasts.
- No. 51. Foreign trade of the United States in forest products, 1851–1908.

No. 55. Meat supply and surplus, with consideration of consumption and exports.
No. 67. Ocean freight rates and the conditions affecting them.
No. 74. Imports of farm products into the United States, 1851–1908.
No. 75. Exports of farm products from the United States, 1851–1908.
No. 89. Marketing grain and live stock in the Pacific coast region.
No. 95. Imports of farm and forest products, 1909–1911.
No. 96. Exports of farm and forest products, 1909–1911.
No. 103. International trade in farm and forest products, 1901–1910.

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Yearbook, Department of Agriculture, statistical appendix.
Yearbook 1903, article, The Nation's Farm Surplus, reprint No. 304.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 297

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ October 28, 1915

CEREAL INVESTIGATIONS ON THE BELLE FOURCHE EXPERIMENT FARM.[1]

By Cecil Salmon,
Formerly Plant Physiologist, Office of Cereal Investigations.

CONTENTS.

INTRODUCTION.

The experiments with cereals at the Belle Fourche Experiment Farm, near Newell, S. Dak., have been conducted for the following purposes: (1) To determine the best crops, varieties, and races for that section; (2) to improve the better varieties by selective breeding; (3) to determine the best methods of cereal production; and (4) to correlate differences in production with climatic and soil conditions in order to determine the principles upon which the best practices are based. The results of these investigations have been reported in part in two previous publications.[2] The present bulletin is intended to bring the work up to date and to include results that for various reasons have not heretofore been given.

[1] The experiments here reported were conducted on the dry-farmed portion of the Belle Fourche Experiment Farm, near Newell, S. Dak. This farm, which is located on the Belle Fourche Reclamation Project, is operated by the Office of Western Irrigation Agriculture of the Bureau of Plant Industry. The experiments were conducted by the Office of Cereal Investigations in cooperation with the Office of Western Irrigation Agriculture. On April 1, 1912, the cooperative agreement between the Office of Cereal Investigations and the South Dakota Agricultural Experiment Station was expanded to include the work at Newell. The writer was in charge of the cereal work on the farm from its beginning (1907) until September 30, 1913, when he resigned to accept another position. He therefore has personal knowledge of all the experiments here reported.

[2] Salmon, Cecil. Dry-land grains for western North and South Dakota. U. S. Dept. Agr., Bur. Plant Indus. Circ. 59, 24 p., 1 fig., 1910.

——— Winter wheat in western South Dakota. U. S. Dept. Agr., Bur. Plant Indus. Circ. 79, 10 p., 1911.

The results of the experiments for six years (1908–1913) are here reported. So short a period is entirely inadequate to settle many of the problems of dry-land grain production. However, a presentation of the results obtained should be of assistance to those engaged in similar work.

DESCRIPTION OF THE FIELD STATION.

It is believed that the results here reported are applicable in general to western South Dakota, northeastern Wyoming, and southeastern Montana. The variations in soil and climate within this section, however, are considerable. To determine just how far the results obtained at Newell are applicable to any other locality, a comparison of soil and climatic conditions is necessary. In order to permit such a comparison, a description of the field station is here given, together with detailed information regarding the temperature and the amount and distribution of the rainfall during the period covered by the experiments.

LOCATION.

The Belle Fourche Experiment Farm is located near the center of the Belle Fourche Reclamation Project, in western South Dakota. The farm is about 24 miles northeast of Bellefourche and 2 miles northwest of Newell. The latitude is about 44° 43′ 45″ N. and the longitude 103° 26′ 15″ W. The elevation is approximately 2,950 feet. About one-half of the farm is irrigated. The portion which is above the irrigation ditch is used for dry-land experiments, including those here reported. The topography of the farm and of the surrounding country is rolling, affording good drainage at all times.

GENERAL PHYSICAL FACTORS.

A study of the crop yields for the series of years here presented may be made more intelligently if combined with a knowledge of the factors which have influenced crop growth. The most important physical factors are (1) the soil, (2) the rainfall and its distribution, and (3) the temperature, especially the length of the growing season as limited by spring and fall frosts. These and other physical data for the Belle Fourche farm are summarized in the paragraphs which follow.

SOIL.

The soil of the Belle Fourche farm and surrounding area is mapped as Pierre clay by the Bureau of Soils.[1] To stockmen and farmers it is familiarly known as gumbo. Table I shows the results of a mechanical analysis of Pierre clay. Its characteristic stickiness is perhaps

[1] Strahorn, A. T., and Mann, C. W. Soil survey of the Belle Fourche area, South Dakota. *In* U. S. Dept. Agr., Bur. Soils Field Oper., 9th Rept., 1907, p. 888. 1909.

explained by the large percentage of clay and silt it contains, these amounting to 35 and 43.2 per cent, respectively.

TABLE I.—*Composition of Pierre clay, as determined by mechanical analysis.*

	Per cent.
Fine gravel	0.2
Coarse sand	1.1
Medium sand	1.4
Fine sand	5.5
Very fine sand	13.0
Silt	43.2
Clay	35.0

The soil is a very heavy, stiff, impervious residual clay. It is somewhat deficient in humus, but is probably well supplied with the mineral elements of plant food. The imperviousness of the soil and the topography of the country cause considerable loss of water by run-off during heavy rains.

Plowing is difficult and expensive. Other necessary field operations, such as disking, harrowing, etc., are accomplished without difficulty. If these operations are performed at favorable times, the soil is easily put in excellent condition.

There is considerable variation in the soil on the experiment farm, even within the limits of a single field. As a general rule, the higher land is lighter in texture, better supplied with humus, and more productive. The lower land is heavier, more impervious to water, contains less humus, and is more difficult to work and to get into condition for cropping.

NATIVE VEGETATION.

The native vegetation of the locality consists largely of western wheat-grass (*Agropyron smithii, A. occidentale*) and buffalo grass (*Bulbilis dactyloides*). Grama grass (*Bouteloua oligostachya*) and needle grass (*Stipa comata*) are frequently found. Buffalo grass usually occupies the higher and lighter soils, especially where Pierre clay is the soil type. Western wheat-grass is confined mostly to the lower slopes and bottoms. On bottom lands subject to overflow this grass produces considerable hay of excellent quality.

Weeds, such as sunflower (*Helianthus petiolaris*), gum weed (*Grindelia squarrosa*), goosefoot (*Atriplex volutans*), and wild parsley (*Peucedanum foeniculaceum*), are plentiful. They are particularly abundant following extremely dry seasons, when the grass may be so injured that weeds are practically the only vegetation. Marsh elder (*Iva axillaris*) is of considerable economic importance because of the difficulty of eradicating it in cultivated fields. This plant commonly is called gumbo weed in this locality because it is found usually on the more impervious soils of the Pierre-clay type.

PRECIPITATION.

The climate of western South Dakota is fairly typical of that of the semiarid Great Plains, which extend from western Texas into the prairie provinces of western Canada. The precipitation decreases steadily from the eastern border of the State to the western, being least in the northwest corner.

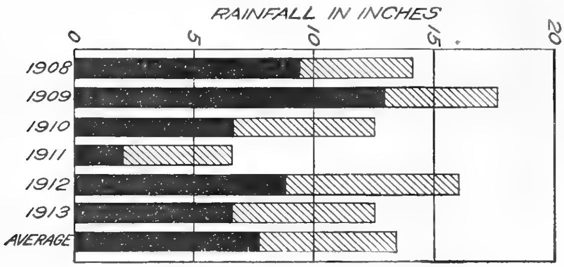

Fig. 1.—Diagram showing the annual and seasonal precipitation at the Belle Fourche Experiment Farm, for six years, 1908 to 1913, inclusive. Solid bars show the seasonal precipitation, while the total length of the bars shows the annual precipitation.

The Black Hills modify the climate of the immediately surrounding country to a great extent, mainly by increasing the precipitation. This effect extends several miles beyond the outlying foothills. The Belle Fourche farm is situated about 30 miles from the foothills and, so far as known, is not influenced to any extent by proximity to the Black Hills. The annual and average precipitation by months at the Belle Fourche Experiment Farm for the six years from 1908 to 1913 is given in Table II. Except as noted, these data were recorded at the station. The annual and seasonal rainfall is shown graphically in figure 1.

Table II.—*Monthly, seasonal, and annual precipitation at the Belle Fourche Experiment Farm for the six years from 1908 to 1913, inclusive.*

[Data (in inches) from the records of the Biophysical Laboratory of the Bureau of Plant Industry, except as noted.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Seasonal.	Total.
1908	[a]0.20	[a]0.19	[a]1.65	1.16	3.95	1.47	1.26	0.62	0.52	[a]2.10	[a]0.20	[a]0.91	9.49	14.23
1909	[a].17	[a].23	[a].19	.84	3.87	5.59	2.45	.55	1.07	.76	.73	1.28	12.94	17.73
1910	.73	.70	.93	1.57	1.26	1.51	1.42	1.03	2.92	.27	.11	.10	6.69	12.55
1911	.13	.05	.09	.17	.45	.50	.80	1.86	.92	.39	.98	.30	2.01	6.64
1912	.24	.10	.71	2.32	2.26	.29	3.20	2.80	3.49	.51	.04	.13	8.78	16.09
1913	.57	.24	.99	.25	1.98	3.10	.35	.26	2.38	1.86	.10	.45	6.67	12.53
Average	.37	.26	.76	1.05	2.29	2.08	1.58	1.19	1.88	.97	.36	.53	7.76	13.41
Maximum	.73	.70	1.65	2.32	3.95	5.59	3.20	2.80	3.49	2.10	.98	1.28	12.94	17.73
Minimum	.13	.05	.09	.17	.45	.29	.35	.26	.52	.27	.04	.10	2.01	6.64

[a] From records of the United States Weather Bureau at Vale and at Orman, S. Dak.

The average precipitation at the Belle Fourche Experiment Farm during the 6-year period under discussion (1908–1913), as shown in Table II, was 13.41 inches. Of this total, 7.76 inches fell during the months from March to July, inclusive, or during the period when small grains make most of their growth. The annual precipitation varied from 6.64 inches in 1911 to 17.73 inches in 1909. The seasonal precipitation (March to July, inclusive) for the same years varied from 2.01 to 12.94 inches.

The average precipitation at the Belle Fourche Experiment Farm is very near the normal for the western part of the State. The period during which experiments have been conducted includes three years in which the precipitation was less than the normal, one of them being the driest known in the history of the State, and three years in which the precipitation was above normal.

In order to make practical use of field experiments, it is necessary to know to what extent the conditions under which they were conducted are likely to continue through a considerable period of time. For this reason Table III, which gives the annual precipitation at Fort Meade, S. Dak., for a period of 35 years (1879–1913) is included.

The record of precipitation at Fort Meade is practically continuous since 1879. Where there have been omissions, it has been completed from the records at near-by points.

TABLE III.—*Monthly, seasonal, and annual precipitation at Fort Meade, S. Dak., for 35 years, 1879 to 1913, inclusive.*

[Data (in inches) from the records of the Weather Bureau.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Seasonal.	Total.
1879	......	......	......	......	......	......	0.78	1.40	0.14	1.60	0.04	0.89	......	......
1880	0.38	1.00	0.92	0.75	......	4.68	1.62	3.91	T[a]	.54	.44	.39	......	......
1881	.56	1.30	.95	1.10	3.33	2.66	1.50	1.57	1.00	.63	.46	T[a]	9.54	15.06
1882	.10	.10	.60	4.77	3.87	5.47	3.05	.44	.26	.49	.05	.12	17.76	19.32
1883	2.90	.30	2.16	4.50	9.61	1.56	2.80	.18	1.60	.67	.05	.72	20.63	27.05
1884	.37	.33	2.26	5.04	8.58	.48	1.20	2.30	.23	.75	.53	.90	17.56	22.97
1885	.32	.23	.52	1.30	.64	3.38	1.52	3.22	.28	.74	.93	.17	7.36	13.25
1886	.32	.67	.88	2.17	.57	.90	3.38	1.50	.40	.40	1.60	.72	7.90	13.51
1887	.56	.20	.76	2.12	2.72	1.76	4.46	4.25	1.10	.40	.24	.36	11.82	18.93
1888	1.65	1.29	.75	.20	3.94	5.50	2.64	3.54	.02	.14	.16	.17	13.03	20.00
1889	.27	.85	.12	2.64	2.02	1.60	6.38	0	.67	1.71	.88	.86	12.76	18.00
1890	.55	.46	1.24	1.65	2.31	6.30	.16	1.64	.76	.38	.40	.38	11.66	16.23
1891	.78	.83	1.63	2.29	6.60	4.29	1.75	1.50	.87	.41	.52	.32	16.56	21.79
1892	1.36	.27	.67	5.70	3.30	3.99	1.04	2.93	.32	2.46	1.51	1.54	14.70	24.09
1893	.40	.74	2.41	3.45	2.01	1.63	1.14	.70	0	3.48	1.48	1.68	10.64	19.12
1894	.55	.12	3.08	3.48	1.15	3.80	.57	.42	.62	1.24	1.03	.72	12.08	16.78
1895	.85	[b]1.05	[b]2.26	2.91	3.35	5.05	.55	.95	.80	.23	2.36	.40	14.12	20.76
1896	.66	1.14	3.43	2.51	2.69	2.62	.72	.05	2.46	T[a]	1.27	.06	11.97	17.61
1897	1.33	.05	1.36	1.80	1.07	5.32	2.05	3.11	.01	.02	.50	T[a]	11.60	16.62
1898	1.20	.15	.83	1.20	9.60	2.70	1.20	1.50	1.80	1.54	.33	1.10	15.53	23.15
1899	.91	.46	1.42	4.15	6.75	2.35	.29	.30	1.10	1.94	.14	.56	14 96	20.37
1900	.50	.34	1.14	.95	.35	3.00	2.05	1.90	2.03	.46	.50	.70	7.49	13.92
1901	.47	.99	1.71	1.68	2.83	6.78	2.83	2.75	1.35	.83	.17	.89	15.83	23.28
1902	1.53	2.30	5.53	3.80	3.35	3.57	1.11	.07	.75	.10	.01	.07	17.36	22.19
1903	.50	.90	1.70	2.55	3.36	2.16	4.25	3.56	2.90	.40	.80	.81	14.02	23.89
1904	.26	1.22	.31	.96	4.52	5.76	.40	2.35	.45	1.86	.16	.72	11.95	18.97
1905	.97	.21	1.14	.49	5.94	4.84	10.33	.62	.12	4.95	.64	.12	22.74	30.37
1906	.30	1.42	2.25	.25	5.37	1.85	1.45	5.55	.12	1.20	.92	1.30	11.17	21.98
1907	.60	.40	.30	.85	10.95	8.10	6.23	.04	1.40	0	0	.33	26.43	29.20
1908	.10	1.00	1.15	2.80	3.98	1.87	.50	[b].80	.58	2.20	.32	1.70	10.30	17.00
1909	.12	.12	.42	2.23	10.20	8.53	3.19	.30	1.50	.50	1.70	1.31	24.57	30.12
1910	.57	.10	1.55	2.00	2.70	1.70	1.62	1.44	3.49	.52	1.06	.13	9.57	16.88
1911	.17	.45	[c].09	[c].47	[c].04	[c].62	[c].58	[c]2.29	[c].97	[c]1.06	[c]1.08	[c].58	1.80	8.40
1912	[c].09	.31	1.19	2.90	1.91	.70	2.78	9.15	2.50	.80	T	1.02	9.48	23.35
1913	.95	.60	3.30	.40	3.10	2.08	.25	.93	.68	[c]2.37	[c].14	.30	9.13	15.10
Mean	.68	.64	1.47	2.24	4.02	3.57	2.18	1.92	.94	1.06	.61	.63	13.45	19.86

[a] T=trace.
[b] Record missing; estimated from the records at near-by stations.
[c] Record missing; rainfall at Vale, S. Dak., about 15 miles north of Fort Meade, substituted.

Fort Meade is only about 25 miles south of Newell, but the elevation is 675 feet greater. Its proximity to the Black Hills apparently influences the rainfall to a considerable extent, as the annual precipitation is greater at Fort Meade than at Newell in those years for which the rainfall records of both are available. A comparison of Tables II and III, however, will indicate to some extent the frequency with which conditions of precipitation similar to those prevailing from 1908 to 1913 are to be expected.

The mean annual rainfall at Fort Meade, as shown by Table III, is 19.86 inches for the 33 years from 1881 to 1913. The maximum rainfall for the period, 30.37 inches, was recorded in 1905. The minimum rainfall, 8.40 inches, was recorded in 1911. For practically all of this year, however, there are no records at Fort Meade, so that the rainfall at Vale, S. Dak., has been substituted. The rainfall at Vale is usually considerably lower than at Fort Meade, though the two points are only about 16 miles apart. The lowest annual rainfall actually recorded at Fort Meade is 13.25 inches, the record for 1885.

The rainfall during the growing period for cereals (March to July) also shows a wide variation. The average seasonal rainfall for the 33-year period is 13.45 inches. The maximum rainfall for the five months, 26.43 inches, was recorded in 1907; the minimum (except that of 1911 at Vale), 7.36 inches, was recorded in 1885. In the six years covered by the experiments at Newell the rainfall at Fort Meade during the growing season has exceeded the normal only in 1909.

EVAPORATION.

The seasonal evaporation probably ranks next in importance to seasonal precipitation among the factors which influence the growth of crops at Newell. The daily evaporation has been recorded at the Belle Fourche Experiment Farm, and the total amount in inches by months from April to July is shown in Table IV. The record of evaporation was not kept for the month of March, but at Newell crops ordinarily make little growth during that month and hence this omission is not of importance. The evaporation is determined from a free water surface, the method being that employed at all of the stations where the Biophysical Laboratory of the Bureau of Plant Industry has been cooperating.[1]

The average evaporation for the four months from April to July, inclusive, for the six years from 1908 to 1913 was 27.620 inches. The lowest total evaporation, 23.627 inches, was recorded in 1909, the year of the greatest rainfall during the same months. The highest total evaporation, 33.906 inches, was recorded in 1911, the year of the lowest seasonal rainfall. Thus, the evaporation usually varies inversely with the precipitation, though this is not always the case.

[1] Briggs, L. J., and Belz, J. O. Dry farming in relation to rainfall and evaporation. U. S. Dept. Agr., Bur. Plant Indus. Bul. 188, p. 16–20. 1910.

TABLE IV.—*Monthly precipitation and evaporation from a free water surface at the Belle Fourche Experiment Farm, by months, from April to July of each year, 1908 to 1913, inclusive.*

[Data (in inches) from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	April.		May.		June.		July.		Total.		Ratio.
	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	
1908	1.16	5.535	3.95	5.917	1.47	6.821	1.26	8.081	7.84	26.354	1: 3.36
1909	.84	3.657	3.87	6.413	5.59	5.859	2.45	7.698	12.75	23.627	1: 1.85
1910	1.57	5.408	1.26	5.306	1.51	8.975	1.42	10.429	5.76	30.118	1: 5.23
1911	.17	4.649	.45	8.302	.50	10.241	.80	10.714	1.92	33.906	1:17.66
1912	2.32	4.849	2.26	6.423	.29	8.175	3.20	7.980	8.07	27.427	1: 3.40
1913	.25	4.705	1.98	4.302	3.10	7.046	.35	8.235	5.68	24.288	1: 4.26
Average.	1.05	4.801	2.29	6.110	2.08	7.853	1.58	8.856	7.00	27.620	1:3.95

The ratio of precipitation to evaporation, also given in Table IV, shows the evaporation for the six years to be 3.95 times the precipitation. In 1909 the ratio was the narrowest, the evaporation for that year being only 1.85 times the precipitation. In 1911 the ratio was the widest, the evaporation being 17.66 times the precipitation. The ratios of precipitation to evaporation for the different years compared with the average ratio for the entire period afford an excellent basis for judging the seasonal conditions under which the experiments reported in this bulletin were conducted.

WIND.

The record of wind measurements has been taken at the Belle Fourche Experiment Farm during the growing season since May, 1909. The anemometer stands near the evaporation tank, at a height of about 2 feet from the surface of the ground. The average wind velocities in miles per hour during the months from April to July for the years 1908 to 1913, inclusive, are presented in Table V.

TABLE V.—*Average wind velocity at the Belle Fourche Experiment Farm, by months, from April to July of each year, 1908 to 1913, inclusive.*

[Data (in miles per hour) from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Month.	1908	1909	1910	1911	1912	1913	Average.
April	....	9.1	9.2	9.2	9.5	6.2	8.6
May	8.3	10.1	8.2	11.6	11.1	5.9	9.2
June	7.2	6.2	9.3	9.1	7.6	6.8	7.7
July	5.0	6.0	7.7	7.9	6.0	5.8	6.5
Average	6.8	7.8	8.6	9.5	8.6	6.2	8.0

Table V shows the average wind velocity at Newell to be 8 miles per hour from April 1 to July 31. The greatest average wind velocity, 9.2 miles per hour, is for the month of May. In June and July there is a considerable decrease in the velocity of the wind, the average for the latter month being 6.5 miles. The greatest seasonal velocity was recorded in 1911, which was the year of least rainfall and greatest evaporation. The highest average velocity for the entire period was recorded in May of that year, 11.6 miles per hour. The average velocity for both June and July was also unusually high. The low yields in 1911 were due to the combination of very low rainfall, high evaporation, and injury to crops from high winds. The wind for any one day (24 hours) seldom exceeds a total of 500 miles, while for any one day during June and July it is usually much less than 250 miles.

TEMPERATURE.

The temperatures at the Belle Fourche Experiment Farm are recorded throughout the year by means of maximum, minimum, and dry-bulb thermometers. A summary of the mean, maximum, and minimum temperatures from April to July, inclusive, for the six years from 1908 to 1913 is presented in Table VI.

TABLE VI.—*Mean, maximum, and minimum temperatures at the Belle Fourche Experiment Farm, by months, from April to July of each year, 1908 to 1913, inclusive.*

[Data (in °F.) from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	April.			May.			June.			July.			Seasonal mean.
	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	
1908	48	89	5	52	79	29	63	90	39	73	100	43	59
1909	38	73	6	52	84	22	66	95	45	70	100	41	56
1910	51	89	24	52	81	27	68	108	36	76	109	44	62
1911	43	88	13	58	94	23	73	101	43	71	105	41	61
1912	47	78	22	55	84	32	66	101	39	70	94	40	60
1913	48	89	24	53	95	26	66	98	45	70	101	42	59
Average	46	84	16	54	86	26	67	99	41	72	101	42	59.5

Table VI shows that the highest average mean, maximum, and minimum temperatures have been recorded in July, though the maximum and minimum temperatures are only very slightly higher than those recorded in June. During the six years, frost has not occurred in June, the lowest minimum temperature recorded being 36° F. This table shows that the average mean temperature for the growing season for cereals for the six years is 59.5 ° F. The greatest variation from this average in any one year was in 1909, when the seasonal mean was 56° F.

The temperature of western South Dakota is somewhat higher than that of corresponding latitudes in the eastern part of the State. This is shown in Table VII, in which the mean monthly and annual temperatures at Newell, Camp Crook, Aberdeen, Pierre, and Brookings are given. Camp Crook is near the northwestern corner of the State, about 60 miles north and 30 miles west of Newell. Aberdeen is directly east of Camp Crook, but is about 90 miles from the eastern boundary. Pierre is on the Missouri River in the central portion of the State. Brookings is in the same latitude as Pierre, but within 20 miles of the eastern boundary.

TABLE VII.—*Mean monthly and annual temperatures at Newell, Camp Crook, Aberdeen, Pierre, and Brookings, S. Dak., for the periods indicated.*

[Data (in °F.) for Newell from the records of the Biophysical Laboratory of the Bureau of Plant Industry and for other stations from the records of the United States Weather Bureau.]

Months.	Newell.	Camp Crook.	Aberdeen.	Pierre.	Brookings.
	6 years (1908–1913).	20 years (1894–1913).	23 years (1891–1913).	21 years (1893–1913).	24 years (1890–1913).
January	[a] 15.0	17.7	9.6	14.1	12.2
February	[a] 19.0	18.9	11.2	16.9	13.8
March	[a] 31.8	28.2	26.2	29.4	28.5
April	45.8	43.9	44.8	46.7	45.0
May	53.7	54.1	55.9	59.1	55.2
June	67.0	63.2	66.1	69.1	65.1
July	71.7	69.5	70.9	75.2	69.6
August	69.7	68.7	68.7	73.3	67.9
September	59.0	58.6	59.0	62.9	59.7
October	45.3	45.6	45.7	48.9	46.3
November	33.2	31.3	28.8	32.0	29.5
December	21.3	23.7	16.9	20.5	19.6
Annual	44.4	43.6	42.0	45.7	42.7

[a] For five years only.

The record of mean temperatures at Newell is for a much shorter period than the records for the other localities noted in Table VII, so that the figures are not entirely comparable. The annual mean and monthly mean temperatures at Newell differ only slightly from those at Camp Crook.

The annual mean temperatures in western South Dakota are shown to be slightly higher than those in the eastern part of the State. The difference between the mean temperature at Camp Crook and at Aberdeen is 1.6 degrees, while that of Pierre is 3 degrees higher than that of Brookings. The variation between the Brookings and Pierre temperatures is quite constant throughout the year, but most of the variation between the Camp Crook and Aberdeen temperatures occurs in December, January, and February. The average of the mean temperatures for these three months is 7.9 degrees lower at Aberdeen. This variation in winter temperatures perhaps accounts for the fact that winter wheat is more likely to winterkill in eastern than in western South Dakota.

Table VIII gives the dates of the last spring and first fall frosts and the number of days in the frost-free period during each year from 1908 to 1913, inclusive. The latest date on which frost has occurred in the spring during the six years was May 23, and the average date was May 13. The earliest frost in the autumn during this period was on August 27, while the average date of the first frost was September 14. The average frost-free period for the six years is 123 days.

TABLE VIII.—*Dates of killing frosts, the last in spring and the first in autumn, with temperatures recorded and length of the frost-free period for each year from 1908 to 1913, inclusive, at the Belle Fourche Experiment Farm.*

[Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	Last frost in spring.		First frost in fall.		Frost-free period.	Year.	Last frost in spring.		First frost in fall.		Frost-free period.
	Date.	Temperature.	Date.	Temperature.			Date.	Temperature.	Date.	Temperature.	
		°F.		*°F.*	*Days.*			*°F.*		*°F.*	*Days.*
1908	May 20	29	Sept 26	22	129	1912	May 4	32	Sept. 23	32	141
1909	May 17	26	Sept. 23	31	128	1913	May 6	32	Sept. 24	29	140
1910	May 23	31	Aug. 25	32	93						
1911	May 11	30	Aug. 27	32	107	Average	May 13	......	Sept. 14	......	123

EXPERIMENTAL METHODS.

The tests with dry-land cereals on the Belle Fourche Experiment Farm have been conducted in field plats and in the nursery. In the field plats varietal tests and tests of rates and dates of seeding have been included. The plats have ranged from one-fiftieth to one-tenth of an acre in size. In the cereal nursery the varieties have been grown in short rows. The use of the nursery has made it possible to test economically a much larger number of varieties than could have been grown in the field plats. Careful records have been kept of the behavior of the varieties included in both the plat and nursery experiments.

PLAT EXPERIMENTS.

The field tests have included varietal tests of winter wheat, rye, and emmer and of spring wheat, oats, barley, and flax. There have also been rate-of-seeding tests with spring wheat and oats and date-of-seeding tests with flax and winter wheat.

SIZE OF PLATS.

All of the plat experiments in 1908 and 1909 and nearly all in 1910 were conducted on tenth-acre plats. These plats were 2 rods wide by 8 rods long. They were arranged side by side in series, the plats in the series being separated by 5-foot alleys. The series were separated by 16.5-foot or 20-foot roads. Each plat thus had a 5-foot alley along each side and a 16.5-foot or 20-foot road along each end.

Most of the tests in 1911 and all of those in 1912 and 1913 were in plats made by sowing a single drill width across an 8-rod series. As the drill was 6 feet wide, this gave a plat of one-fifty-fifth of an acre in area. The alleys between these plats have been 19.2 inches in width. By the use of plats and alleys of these dimensions it was possible to sow five plats within the area formerly occupied by one tenth-acre plat. As the plants draw considerable moisture and plant food from the alleys, it has been thought fair to consider these one-fifty-fifth-acre plats as one-fiftieth-acre plats in computing acre yields.

REPLICATION OF PLATS.

In 1908, 1909, and 1910, when the tests were conducted on tenth-acre plats, there was only a single plat of each variety. Check plats of standard varieties of each cereal were sown at regular intervals in 1909 and 1910, and in most of the tests in 1908. As this method did not appear to be entirely satisfactory, a change was made in 1911 in some of the tests and in all those conducted in 1912 and 1913. The size of the plats was reduced, as stated in the preceding paragraph, and the tests were replicated. In the varietal tests, five plats of each variety were grown. In rate-of-seeding and date-of-seeding experiments it has been considered sufficient to grow three plats of each rate or date, as there is a correlation between the different parts of the experiment which is not found in the varietal tests.

PREPARATION OF THE LAND.

In preparing the land for experimental work the aim has been to keep within practical farm limits as far as possible. The plowing has been done at a moderate depth, 6 to 8 inches, and subsequent treatment has been in accord with the best farm practice. The necessity for keeping the land uniform has sometimes required hand work, such as the removal of weeds, and probably more cultivation at times than would be done by a practical farmer. The work also has been more timely than is usually the case on large farms.

Most of the experimental work has been on land fallowed during the preceding year. Fallowing also has been necessary to insure uniformity in soil conditions. When the experimental work was begun, this appeared to be the most practicable method of producing crops under dry-land conditions.

The usual practice has been to plow in the fall after the crop was removed, or the following spring if conditions were not favorable for fall plowing. Ground plowed in the fall has been left rough or has been worked down with the disk and spike-tooth harrows, according to the moisture condition. If it contained considerable moisture it was worked; otherwise it was not. All fallow has been worked when necessary to remove weeds or to prevent evaporation. The spring-tooth harrow has proved to be the most satisfactory tool for working fallow land. Other implements, such as the smoothing harrow and disk harrow, pulverize the soil to a greater extent and increase the danger from soil blowing.

The only varietal tests here reported which were not conducted on fallowed land are those with oats, barley, and flax in 1913. The varietal test of oats was on corn ground, which was disked and harrowed into good condition before seeding. The barley varieties were grown on land cropped to wheat the previous season, which was plowed about 10 inches deep soon after the wheat was taken off and was worked down with disk and harrow immediately after plowing. The flax varieties were sown on land on which small grain was grown in 1912, the preparation being the same as that for barley.

The rate-of-seeding test with spring wheat in 1910 and with oats in 1913 and the date-of-seeding test with flax in 1913 were on land on which corn was grown the previous year. The land was disked and harrowed but was not plowed before seeding. The rate-of-seeding test with spring wheat in 1913 was on land cropped to small grain the preceding season and prepared the same as that for the barley varieties.

RATES AND DATES OF SEEDING.

The usual rate of seeding for spring wheat has been from 4 to 5 pecks to the acre; for winter wheat, 3 pecks; for oats, 6 pecks; for barley, 5 pecks; and for flax, 2 pecks.

Spring grains have been sown as early as seemed practicable, seldom before April 1 or later than April 15. Winter grains have been sown at what was thought to be the most favorable date each year. This has usually been between September 15 and October 1.

NURSERY EXPERIMENTS.

The nursery tests at Newell have included varieties newly introduced and those of which there was not sufficient seed for sowing in the field plats, and also pure-line selections from the better commercial varieties. The latter has been the most important feature of the nursery work. The varieties and selections have been grown in short rows, thus making possible the economical testing of a very much larger number of varieties and races than could have been included in the plat tests.

NATURE OF THE WORK.

Although the improvement of the cereal crops by selection has required a considerable outlay of time and money, the results are less than were expected at the outset. This is due to several causes, the most important of which are the partial or complete crop failures resulting from the extremely dry seasons. This has prevented sufficient increase of the more desirable strains for a thorough test in field plats. In many cases the drought has been so severe that all the races and varieties failed to mature grain, regardless of their ability to evade or resist moderate droughts.

When work was begun at the Belle Fourche Experiment Farm, the best crops and varieties for that section were fairly well known. It seemed, therefore, that the best plan in crop improvement was to select from these few varieties rather than from many which might prove to be unadapted. As the better varieties were for the most part unselected, this line of work seemed to be specially promising.

It appeared that isolation of these types and a study of their characteristics and values ought to precede attempts to improve them by hybridization. Accordingly, in 1908, several hundred selections were made from winter wheat, spring durum wheat, spring common wheat, and oats. These were mainly from Turkey, Kharkof, and Crimean winter wheat, Kubanka durum wheat, and Sixty-Day and Kherson oats. Additional selections from these and other varieties were made in subsequent years.

NURSERY METHODS.

Single heads were selected from the field plats, the aim being to obtain as many types as possible. Each head was described carefully before it was thrashed. The seeds from each head were then sown in a 5-foot row. The number of kernels sown in each row was usually 25. The dates of planting, emergence, heading, and ripening were recorded, as were such other notes on hardiness, yield, etc., as appeared to be desirable. At harvest the rows which seemed to be especially undesirable were discarded, but in all cases at least one selection of each type was retained for further study. Most of these races which were retained were sown with an ordinary grain drill in 60-foot rows in 1910 and succeeding seasons. As far as possible, replicate plantings have been made, but loss of seed in unfavorable seasons and lack of land and labor have made impossible as frequent replication as has seemed desirable.

INTERPRETATION OF EXPERIMENTAL RESULTS.

The best variety or method of culture is the one which, on the average, will produce the highest yield of grain of the greatest value at the least cost. It is seldom that a single variety or method will fulfill all these requirements for all seasons. Usually one will give the best results one season, another the second, and perhaps still another the third. The best method or variety, presumably, is that one which gives the best average during a series of years, provided the seasons are representative. In actual practice, however, the problem is more complicated than would appear from this statement. The variation in soil and in seasons, the importance of weather and soil conditions at critical stages of growth, and the variable reaction of varieties to seasonal conditions make it difficult to arrive at definite conclusions by a study of averages alone.

EXPERIMENTS WITH WHEAT.

The experiments with wheat at Newell have included plat and nursery tests of both spring and winter varieties. In addition to the varietal tests there have been rate-of-seeding experiments with spring wheat and date-of-seeding experiments with winter wheat.

Because there is always a ready market for the grain and its value is high in comparison with its bulk, wheat is always an important crop in a newly settled district. For that reason the experiments with wheat at Newell have been more extensive and of greater popular interest than those with any other grain. Considerable effort has been devoted to the improvement of varieties by selection.

SPRING WHEAT.

Spring wheat is much more commonly grown in western South Dakota than winter wheat. There is considerable diversity in varieties, for both common and durum wheats are grown. The common wheats include representatives of the Fife, bluestem, and Preston (bearded Fife) groups. A varietal test of spring wheat has been conducted on the Belle Fourche Experiment Farm each year since 1908. A rate-of-seeding test with Kubanka durum wheat was begun in 1909 and was continued throughout the period here discussed.

VARIETAL TEST OF SPRING WHEAT.

The spring-wheat varieties included in the tests at Newell are those which have given the best results in other dry-land districts, with the addition of a few which have been introduced recently from foreign countries. Because so many of the poorer ones were eliminated by previous tests elsewhere, the varieties grown at Newell do not show wide variations in yield.

Twelve varieties and strains of durum wheat and thirteen of common wheat have been grown in plats. In some cases several lots of the same variety from different sources have been included in the test. Therefore, only 6 varietal names of durum and 10 of common wheat are represented by the 25 lots. The annual and average yields for all varieties and strains are shown in Table IX.

As shown in Table IX, good yields of spring wheat were produced in 1908, 1909, and 1913, fair yields of some varieties in 1910, and failures of practically all varieties in 1911 and 1912. Only five of the durum varieties and strains and five of the common varieties have been grown during all of the six years (1908–1913).

TABLE IX.—*Annual and average yields of varieties of spring wheat on the Belle Fourche Experiment Farm, 1908 to 1913, inclusive.*

Group and variety.	C. I. No.[a]	Yield per acre (bushels).						
		1908	1909	1910	1911	1912	1913	6-year average.
Durum:								
Adjini	2941	18.3						
Arnautka	1493	22.3	22.6	8.3	0	0	17.1	11.7
Do	1537			11.5	0	0		
Do	1547	21.3	22.0	9.2	0	0		
Kubanka	1354	24.8	19.5	4.0	0	0		
Do	1440	24.9	[b]21.4	[c]7.4	0	0	15.6	11.6
Do	1516	[c]23.8	22.6	5.3	0	0	19.1	11.8
Do	2246	21.0						
Do	2882	23.2						
Pelissier	1584	21.7						
Pererodka	1350	22.5	23.2	5.2	0	0	16.7	11.3
Yellow Gharnovka	1444	22.7	20.9	5.0	0	0	16.5	10.9
Fife:								
Ghirka	1517	16.2	11.7	12.8	0	1.9	16.3	9.8
Glyndon (Minn. No. 163)	2873					0	15.8	
Marquis	3276					3.8	16.8	
Power	3025	18.5	17.3	10.6	0	0	16.6	10.5
Rysting	3022	19.3	15.0	10.3	0	0	15.0	9.9
Bluestem:								
Haynes	2874					0	14.2	
Do	3020	18.3	13.8	9.0	0	0	14.1	9.2
Do	3021	17.0						
Preston:								
Preston	3081					0	19.5	
Do	3087					0	19.0	
Spring Turkey	4154					0	16.2	
Miscellaneous:								
Changli	2911					11.7	14.6	
Manchuria	2492	16.2	16.0	12.8	0	4.5	17.1	11.1

[a] Cereal Investigations number. [b] Average of two check plats. [c] Average of three check plats.

The rainfall in 1908 and 1909 was fairly heavy and its distribution was particularly favorable to spring grains, as the greater portion came during the growing season. In 1910 the ground was in excellent condition for seeding and the prospects for a crop were excellent until about June 1. The rainfall was so light during the growing season, however, that many of the varieties did not produce grain. There were only two rains of more than 0.5 inch between April 15 and the time the wheat matured, and these two only slightly exceeded that quantity. As a shower of less than 0.5 inch is soon evaporated and is of little benefit to growing crops, particularly in a dry season, the conditions were especially trying during 1910. The moisture stored in the soil the previous season was the principal factor in crop production.

A surprising feature of the varietal test in 1910 was the larger yields produced by the common spring wheats in a season when it appeared that the durum varieties should have yielded best. The production of straw of the latter was sufficient for a heavy yield of grain, much greater than from the common varieties. From the appearance of the plats they seemed to have withstood the drought better than the common wheats, but when they matured it was found that many heads contained little or no grain. The only explanation of the difference in yield between the durum and common varieties that appears plausible is that the durum wheats bloomed during a hot, dry period, about June 20, while most of the common varieties bloomed about a week later, when weather conditions were more favorable. Low yields of durum wheat were obtained at several stations in the Great Plains in 1910 and 1911, and in every case it was noted that the durum varieties bloomed during a hot, dry period. This matter has been discussed more at length by the writer in another publication.[1]

The crop season of 1911 was so dry that spring grain sown at the usual time did not germinate till August. Table II shows that the total precipitation from March to July, inclusive, was only 2.01 inches and that, with one exception, this precipitation came in such small showers that it was of no value in promoting crop growth. No yields of any of the cereals were produced that year.

The soil was so dry in the spring of 1912 that only small yields were produced that year, even though the precipitation was nearly normal. The rainfall during May and June was light, and this factor contributed further toward the partial failure of the crops. In that year all the replicated plats of only two varieties of spring wheat, the Ghirka and Manchuria, were harvested. Only single plats of the Changli and Marquis were grown; these produced the yields shown in Table IX. None of the other varieties produced enough grain to harvest. All four of the varieties which matured grain in 1912 are early and so in a measure escaped the effect of the drought.

In 1913 five fiftieth-acre plats of each variety were sown, but on a portion of the area the germination and growth were not at all uniform, probably due to the replowing of the land the previous summer to eradicate gumbo weed. Two plats of each variety were sown on land which received uniform treatment, so the results from these plats only are included in Table IX.

Two plats of the Galgalos wheat, C. I. No. 2398, a beardless variety with short, stiff straw and a rather large, soft, white kernel, were grown on land not entirely comparable with that on which the varieties shown in Table IX were sown. Plats of the Kubanka and Power were grown, however, on the same area. The Galgalos produced an average yield of 17.5 bushels, the Kubanka 18.1 bushels, and the Power 14.3 bushels.

SUMMARY OF YIELDS OF SPRING WHEAT.

Of the numerous varieties of spring wheat grown at Newell, only 10 have been included in the test for the entire period of six years. Of these 10 varieties, 5 are durum and 5 are common wheats. Of the common wheats, 3 belong to the Fife group, 1 to the bluestem, and 1,

[1] Salmon, Cecil. Sterile florets in wheat and other cereals. *In* Jour. Amer. Soc. Agron., v. 6, no. 1, p. 24-30, 2 pl., 1914.

the Manchuria, is a bearded wheat which does not belong to any group now commonly grown in this country.

Table X shows the average date of heading and of maturity, height, and weight per bushel of these 10 varieties in 1908, 1909, 1910, and 1913. In 1911 none of the varieties matured grain, so that none of these data are available for that year, while in 1912 data were obtained for only two or three varieties.

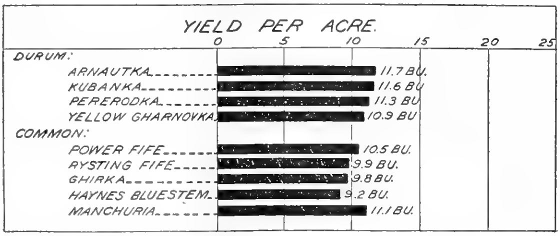

FIG. 2.—Diagram showing the average yields per acre, in bushels, of the leading varieties of spring wheat at the Belle Fourche Experiment Farm, for six years, 1908 to 1913, inclusive.

Table X also shows the average yields per acre of grain and of straw for these varieties. The yield of grain is the average for the entire period of six years, 1908 to 1913. These yields are shown graphically in figure 2. The yield of straw is for five years, 1912 being excluded for the reason that only two of the varieties were harvested, though all of them made some growth. The groups and varieties are arranged in the table according to their average yield of grain per acre.

TABLE X.—*Average dates of heading and of maturity, height, weight per bushel, and yields of the 10 leading varieties of spring wheat on the Belle Fourche Experiment Farm, 1908 to 1913, inclusive.*

[The groups and varieties are arranged according to their average yield per acre.]

Group and variety.	C. I. No.	Date of—		Height.[a]	Weight per bushel.[a]	Yield per acre.	
		Heading.[a]	Maturity.[a]			Grain.[b]	Straw.[c]
Durum:				*Inches.*	*Pounds.*	*Bushels.*	*Pounds.*
Kubanka	1516	July 1	July 27	30	62.2	11.8	1,540
Arnautka	1493	June 30	...do....	33	62.4	11.7	1,570
Kubanka	1440	July 2	July 28	32	61.8	11.6	1,590
Pererodka	1350	...do....	July 30	33	62.5	11.3	1,700
Yellow Gharnovka	1444	...do....	July 28	34	62.4	10.9	1,730
Miscellaneous:							
Manchuria	2492	June 29	July 25	30	58.9	11.1	1,390
Fife:							
Power	3025	July 6	July 28	28	59.7	10.5	1,370
Rysting	3022	July 7	July 29	28	55.9	9.9	1,370
Ghirka	1517	June 27[d]	July 20[d]	[d]27	57.6	9.8	1,200
Bluestem:							
Haynes	3020	July 9	July 30	28	55.4	9.2	1,320

[a] Average for four years (1908–1910 and 1913), except as noted.
[b] Average for six years, 1908 to 1913, inclusive.
[c] Average for five years (1908–1911 and 1913).
[d] Average for two years, 1912 and 1913.

LEADING VARIETIES OF SPRING WHEAT.

As shown in Table X, the best yields of spring wheat at Newell have been obtained from the durum varieties, Kubanka and Arnautka. Some of the varieties of common wheat, however, have produced yields nearly as high as those of the best durum varieties. Brief descriptions of the more important varieties of durum and common wheat grown at Newell are given herewith, and heads of typical varieties are shown in figure 3. A more complete discussion of hard spring-wheat varieties will be found in another publication.[1]

Durum wheat.—The heads of durum wheat[2] are broader and more compact and the beards are longer than those of the spring common varieties. The kernels are large and very hard and are usually clear amber in color. There is considerable variation among the durum wheats in the color of chaff and of beards. The leading varieties at Newell all have yellowish, hairless chaff and yellow beards. They all belong to the Kubanka group of durum wheats.

The highest average yields for the six years from 1908 to 1913, inclusive, were produced by the Kubanka, C. I. Nos. 1440 and 1516, and

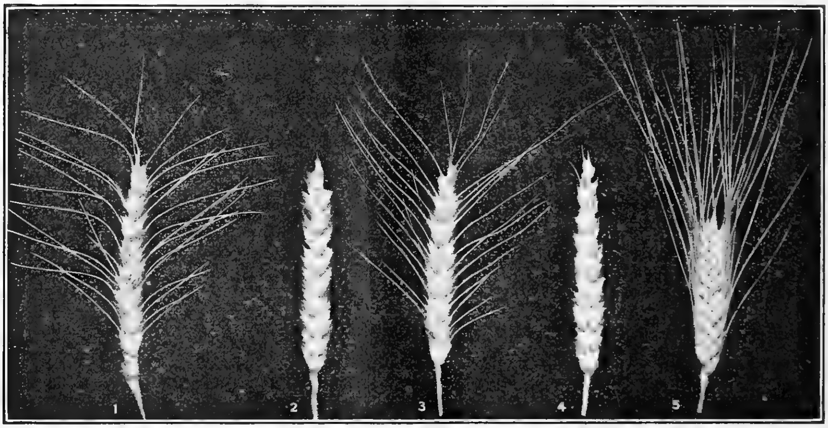

FIG. 3.—Representative heads of the different groups of wheat discussed in this bulletin: *1*, Turkey winter; *2*, Fife; *3*, Preston; *4*, bluestem; *5*, durum.

the Arnautka, C. I No. 1493. There is practically no difference in the average yields of these three lots, nor is there much difference in the appearance of the varieties. Somewhat lower yields were produced by the Pererodka and Yellow Gharnovka varieties, though the difference even here is slight.

All these varieties except the Arnautka were introduced into the United States from Russia by the United States Department of Agriculture in 1899 and have since been grown in the northern Great Plains. The Arnautka variety was brought in and grown by farmers at an earlier date. It is still probably more widely grown than any other durum wheat in the United States, though the quality of the

[1] Ball, C. R., and Clark, J. A. Varieties of hard spring wheat. U. S. Dept. Agr., Farmers' Bul. 680, 20 p., 7 fig., 1915.

[2] For a more complete discussion of durum wheat, see Salmon, Cecil, and Clark, J. A. Durum wheat. U. S. Dept. Agr., Farmers' Bul. 534, 16 p., 4 fig., 1913.

Kubanka is higher. The best durum wheat to grow in western South Dakota is the Kubanka. A field of this variety on the Belle Fourche Experiment Farm is shown in figure 4.

Common wheat.—All the spring common wheats which have been grown at Newell for more than one year have hard or semihard red kernels. They vary chiefly in the hairiness of the chaff, in the presence or absence of beards, and in the quality of the grain.

The highest yield of the spring common wheats has been produced by a variety called Manchuria, C. I. No. 2492. The average yield of this variety for six years is 11.1 bushels, slightly less than that of the best durum wheats. The Manchuria is an early, bearded variety, with hairless, brown chaff, and medium-sized, semihard, red kernels. It has produced fairly good yields at Newell because of its earliness. Its milling qualities are poor and it is not to be recommended.

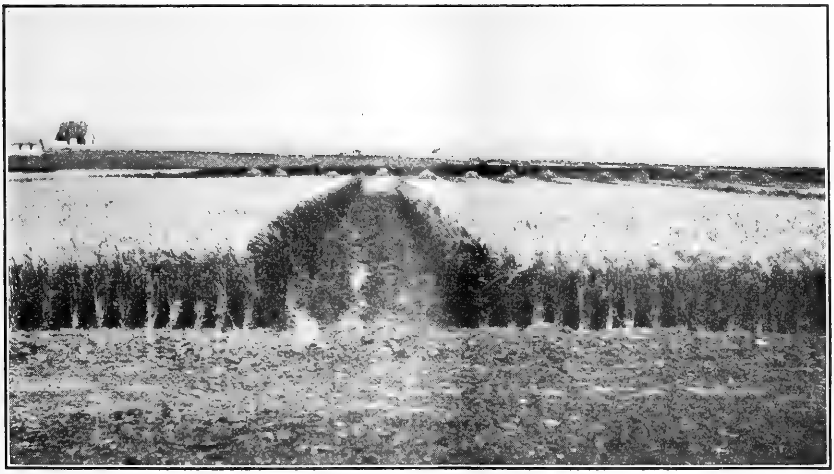

FIG. 4.—Plats of Kubanka durum wheat on the Belle Fourche Experiment Farm in 1910.

Three varieties of Fife wheat have given slightly lower yields than the best durum wheats. These three Fife wheats are the Power, Rysting, and Ghirka. The Power and Rysting are somewhat later in heading than the durum varieties, but mature at about the same time. The Ghirka is slightly earlier than any of the durums.

The Fife is one of the standard groups of hard red spring wheat in Minnesota and the Dakotas. The Fife wheats all have slender, rather open, beardless heads, with white, hairless chaff.

If common spring wheat is to be grown in western South Dakota, some variety of the Fife group should be chosen. In addition to the three here mentioned, the Marquis, a variety which originated in Canada and which has given excellent results in the Canadian Prairie Provinces, is worthy of trial. It is very early in maturing and is of excellent milling quality. The Marquis was one of the few varieties which matured grain in 1912, while in 1913 it produced a slightly higher yield than any other variety of Fife wheat grown at Newell.

The bluestem wheats, another of the important groups of hard red spring wheats, have given rather poor yields at Newell. The only variety which has been grown for the entire six years is the Haynes, C. I. No. 3020. This variety is also known as Minnesota No. 169. The bluestem wheats have beardless heads, with hairy, white chaff. They mature slightly later than the Fife varieties, and for that reason probably have not given as good yields as the latter.

The only other group of common spring wheat of importance in western South Dakota is the Preston (bearded Fife). The varieties of this group have been grown only two years—1912 and 1913. In 1912, in common with practically all other wheat varieties, they produced no grain. In 1913 they produced higher yields than any of the other common wheats. The Preston, C. I. No. 3081, produced the highest yield of any variety under trial that year, including the durums. One or two varieties of the Preston group appear to be worthy of further trial.

RATE-OF-SEEDING TEST OF SPRING WHEAT.

A rate-of-seeding test with Kubanka durum wheat was conducted in 1909, 1910, 1912, and 1913. The seed, the preparation of the ground, and the date of seeding have been identical for all plats. In 1909 and 1912 this test was conducted on land which was fallow the previous year. In 1910 it followed corn and in 1913 was on land which produced a very small crop of wheat the preceding season.

In 1909 and 1910 single tenth-acre plats and in 1912 and 1913 three fiftieth-acre plats were sown at each rate. The rates varied from 2 to 8 pecks per acre, but only the 4, 5, 6, and 8 peck rates were sown in each of the four years. Table XI shows the annual and the average yields of grain and of straw from the different rates of seeding.

TABLE XI.—*Annual and average yields of Kubanka durum wheat in a rate-of-seeding test on the Belle Fourche Experiment Farm in 1909, 1910, 1912, and 1913.*

Rate of seeding.	Yield per acre.									
	1909		1910		1912		1913		Average.	
	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
	Bush.	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*
2 pecks	12.5	870	5.5	1,470	......	......	......	......	......	......
3 pecks	......	......	......	......	0	0	9.3	1,810	......	......
4 pecks	14.4	1,055	5.5	1,270	0	0	9.8	1,860	7.4	1,046
5 pecks	16.8	1,650	2.8	830	0	0	10.4	1,830	7.5	1,077
6 pecks	17.2	1,230	1.8	690	0	0	9.9	1,800	7.2	930
7 pecks	......	......	......	......	0	0	10.3	1,740	......	......
8 pecks	17.9	1,365	3.4	745	0	0	10.6	1,780	8.0	972

In 1909 and 1913, as shown in Table XI, fairly good yields of both grain and straw were obtained. In 1910 the yields were very small, and in 1912 there was not sufficient growth on any of the plats to make them worth harvesting. In the particularly favorable year 1909, the higher rates of seeding gave the best yields. There was little difference in the yields from the different rates in the somewhat less favorable year 1913. In 1910, a very unfavorable year, the plats from the lower rates produced the best yields and in 1912 they made the best growth early in the season. None of the plats, however, produced grain in the latter year.

The average yields of grain for the four years from the 4, 5, 6, and 8 peck rates show very slight variation. The highest yield, 8 bushels to the acre, was produced from the 8-peck rate, while the lowest yield, 7.2 bushels, was produced from the 6-peck rate. The 4-peck rate produced an average yield of 7.4 bushels, only 0.6 bushel less than was produced from sowing 8 pecks. In other words, the extra bushel of seed required at the 8-peck rate produced a gain of only 0.6 bushel in the resulting crop, so that the higher rate really entailed a slight loss. The yield of straw is considerably higher from the 4 and 5 peck rates than from the 6 and 8 peck rates.

While the data here presented are far from conclusive, they indicate that it is safer to sow 4 or 5 pecks of durum spring wheat in western South Dakota than to sow a larger quantity. Because of the smaller size of the kernels of common wheat and the consequent greater number in a peck, the proper rate of seeding for spring common wheat is 3 or 4 pecks to the acre.

NURSERY EXPERIMENTS WITH SPRING WHEAT.

The nursery experiments with spring wheat on the Belle Fourche Experiment Farm have been confined to the testing of pure-line selections of the more important varieties. In 1908 about 100 heads each of durum wheats and of spring common wheats were selected from the varieties in plat tests. These were grown in head rows the following year. In 1910 these selections were grown in 60-foot rows, and in 1911 in 60-foot rows replicated four or five times. The durum-wheat selections were complete failures in 1911 and produced little grain in 1912, so that only a very small quantity of seed was available for testing in 1913. Only slightly better results were obtained from the selections of common wheat.

None of the selections has as yet shown any marked superiority over the parent varieties, though there has been considerable variation among the different selections from the same variety. These variations consist principally of differences in earliness, height, yield, and quality of grain. In many cases a selection which has appeared to be particularly good one year has given poor results the next, so that it can not be said that any material advance has been made. More extensive trials, particularly of the earlier varieties, appear to be desirable.

WINTER WHEAT.

VARIETAL TEST.

Winter wheat has been grown successfully at Newell in four of the six years from 1908 to 1913. In 1911 the spring rainfall was so deficient that the winter wheat died before making much growth, although the winter survival of all varieties was good. In the fall of 1911 the soil was so dry that the wheat did not germinate; hence, no crop was produced in 1912.

Winter wheat has been sown each year on land fallowed the previous summer. The date of seeding in each case has been that which seemed to be most favorable in the particular season. The rate of seeding usually has been 4 pecks to the acre.

The annual and average yields of the varieties of winter wheat grown on the Belle Fourche Experiment Farm from 1908 to 1913 are shown in Table XII.

TABLE XII.—*Annual and average yields of varieties of winter wheat on the Belle Fourche Experiment Farm, 1908 to 1913, inclusive.*

C. I. No.	Variety.	Yield per acre (bushels).						
		1908	1909	1910	1911	1912	1913	Average.
2979	Alberta Red			16.7	0	0	35.0	
1667	Beloglina			19.2	0	0	37.2	
2239	Do			19.2	0	0	39.4	
1435	Crimean	18.7	31.5	19.7				
1437	Do	25.3	36.0	20.3	0	0	36.4	19.7
1442	Kharkof	25.4	40.3	22.7	0	0	38.6	21.2
1583	Do	22.5	39.0	23.6	0	0	38.8	20.7
2208	Do			17.5				
1561	Theiss			19.4	0	0	36.8	
1558	Turkey	24.1	41.0	17.8	0	0	38.1	20.2
1571	Do	25.5	39.0	20.3	0	0	38.7	20.6
2943	Do			15.0	0	0	39.3	
2998	Do			14.2				
3055	Do	22.3	44.5	(1)	0	0	35.0	17.0

1 Did not emerge in the fall.

In the fall of 1907 the winter-wheat varieties were sown on new land which had been broken the previous spring and disked during the summer to keep down weeds. The seven strains grown that year were all of the hard red winter or Turkey group. The varietal names included Turkey, Kharkof, and Crimean. Two sowings were made of each variety, one on September 15 and one on October 5. The plants from both dates of seeding made a small growth before winter. The winterkilling ranged from 25 to 45 per cent in the various plats. The favorable spring conditions caused the plants to tiller, so that at harvest time the stand was about normal. The average yields from the two dates of seeding varied from 18.7 to 25.5 bushels to the acre.

The same varieties were grown in 1909 as in 1908. The growth in the fall of 1908 was small. There was some damage from the blowing of the soil the following spring, for the most part at one end of all the plats. For this reason only a part of each plat was harvested and the yield determined therefrom. The yields were considerably higher than in 1908, ranging from 31.5 to 44.5 bushels. A view of the winter-wheat plats after harvest in 1909 is shown in figure 5.

In the fall of 1909 the number of varieties was increased to 14 by including 7 which had made a particularly favorable showing in nursery plats the previous season. These latter were grown on fiftieth-acre plats, while the other varieties were grown on tenth-acre plats. The preparation of the soil and the date and rate of seeding

FIG. 5.—Winter-wheat plats on the Belle Fourche Experiment Farm after harvest in 1909.

were the same for all plats, however, so that the yields are comparable. One of the strains of Turkey, C. I. No. 3055, did not germinate, but all the other varieties germinated well and made a little growth before winter. The following spring there was some damage from the blowing of the soil, but the winter survival was fairly good, and quite favorable yields were obtained.

In 1911 and 1912, as previously stated, failures were recorded from all of the varieties of winter wheat. In the fall of 1912 eleven varieties were sown under favorable conditions. Three fiftieth-acre plats of each variety were sown instead of a single tenth-acre plat, as in previous years. The growth during the fall was particularly good, and as the winter was mild there was practically no winterkilling. The rainfall during the growing season was sufficient for crop growth, so that yields ranging from 35 to 39.4 bushels to the acre were produced. The highest yield was obtained from the Beloglina, C. I. No. 2239.

Of the fourteen varieties and strains of winter wheat grown on the Belle Fourche Experiment Farm only five have been sown in each of the six years. The average date of heading and of maturity, weight per bushel, and yield of grain and of straw of these five varieties are given in Table XIII. The yields of grain are shown graphically in figure 6. Table XIII shows that there is practically no variation in the date of heading and of maturity and in the weight per bushel of these stocks and that the variation in yield of grain and straw is very slight.

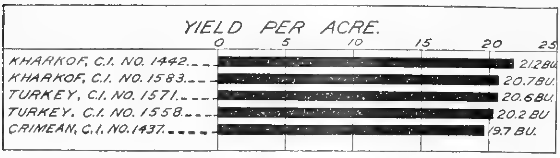

FIG. 6.—Diagram showing the average yields per acre, in bushels, of the leading varieties of winter wheat at the Belle Fourche Experiment Farm, for six years, 1908 to 1913, inclusive.

TABLE XIII.—*Average dates of heading and of maturity, weight per bushel, and yields of five varieties of winter wheat grown continuously on the Belle Fourche Experiment Farm, 1908 to 1913, inclusive.*

C. I. No.	Variety.	Date of—		Weight per bushel.[2]	Yield per acre.	
		Heading.[1]	Maturity.[1]		Grain.[3]	Straw.[4]
				Pounds.	*Bushels.*	*Pounds.*
1442	Kharkof	June 17	July 11	60.9	21.2	1,860
1583	Do	...do	...do	60.3	20.7	1,994
1571	Turkey	...do	...do	60.7	20.6	1,842
1558	Do	...do	...do	60.8	20.2	1,798
1437	Crimean	June 16	...do	60.4	19.7	1,924

[1] Average for 1910 and 1913 only.
[2] Average for 1908–1910 and 1913 only.
[3] Average for the entire period of six years, 1908–1913.
[4] Average for 1908, 1910, 1911, 1912, and 1913.

LEADING VARIETIES OF WINTER WHEAT.

The leading varieties of winter wheat at Newell are the Kharkof, Turkey, and Crimean. These varieties all have bearded heads, with white, hairless chaff, and hard red kernels. They all were imported from southern Russia, the Kharkof and Crimean by the United States Department of Agriculture and the Turkey by Russian immigrants and by commercial agencies. They are not distinguishable in appearance and differ only slightly in yield and in hardiness. It is probable that the Kharkof is slightly hardier than the Turkey or the Crimean, and for this reason it is to be preferred for sowing in western South Dakota.

DATE-OF-SEEDING TEST OF WINTER WHEAT.

A date-of-seeding test has been conducted each year at Newell with Turkey winter wheat, C. I. No. 3055. In this experiment, plats have been sown about the first and fifteenth of each month, from

August 15 to November 1. In addition, all the varieties were sown in the fall of 1907 on two dates, September 15 and October 5. In growing winter wheat in western South Dakota the date of seeding is considered to be next in importance to the selection of the variety and the preparation of the seed bed. The climatic conditions vary so much from year to year that it is difficult to determine this date accurately. The data here printed are believed to be suggestive only.

Table XIV shows the annual and average yields of winter wheat obtained on the Belle Fourche Experiment Farm from seeding on several dates during the years 1908 to 1913.

TABLE XIV.—*Annual and average yields of Turkey winter wheat in a date-of-seeding test on the Belle Fourche Experiment Farm, 1908, 1909, 1910, and 1913.*

Date of seeding.	Yield per acre (bushels).					
	1908	1909	1910	1913	Average. 1908–1910 and 1913.	Average. 1909, 1910, and 1913.
August 1	....	....	....	29.2	....	....
August 16	....	37.5	19.3	28.1	....	28.6
September 1	23.0	39.0	8.3	28.1	24.6	25.1
September 16	20.3	40.5	22.0	(1)	....	....
October 1	24.3	43.0	(2)	28.1	23.8	20.7
October 16	24.7	42.0	13.3	21.4	25.3	25.6
November 1	25.5	37.3	13.2	16.3	23.1	22.3
November 16	....	....	....	16.1	....	....

[1] Not sown because of severe drought. [2] Did not germinate.

As shown in Table XIV, the highest yield in 1908, 25.5 bushels per acre, was produced from the latest seeding. The difference in yield from the various dates of seeding was slight, except that the plat sown on September 16 yielded only 20.3 bushels per acre. The fall of 1907 was dry and the comparatively low winter survival and low yield of the earlier sown plats may have been due to the fact that growth was checked by the drought, and hence the plants did not go into the winter in good condition. In the varietal test, which was sown in duplicate on September 15 and October 5, six of the seven varieties produced higher yields from the later seeding.

The highest yield in 1909 was from the plat sown October 1, with gradual decreases toward the earlier and later seedings. Germination was prompt on the plat sown August 16, but the plants on the plats sown September 1, September 16, and October 1 did not emerge until October 23. Damage from the blowing of the soil prevented taking accurate notes on winterkilling.

In the fall of 1909 the plats were sown in duplicate with the exception of the first date. For some reason there was no germination on the plats sown October 1. The plants on one series of the plats sown on October 16 and November 1 were killed by the blowing of the soil the following spring. The highest yield was obtained from the plats sown on September 16. The poor yield from the plat sown September 1 was due to low germination.

In the fall of 1910 the two sowings germinated at about the same time and the plants made a vigorous growth. The plat sown September 16 showed good germination but less growth than the two earlier seedings. The plants on the plats sown October 1 emerged but made little growth before winter, while in the plats sown October 16 and November 1 the seed germinated but the plants did not emerge. As there was little precipitation during the fall, winter, and spring, practically all of the plants were dead by May 1. There was a higher moisture content and better survival in the late-sown

FIG. 7.—Plats of winter wheat in the date-of-seeding test on the Belle Fourche Experiment Farm. (Photographed October 24, 1912.)

than in the early-sown plats. The fall of 1911 was so dry that the date-of-seeding as well as other tests with winter wheat were a complete failure.

In the fall of 1912 the test was replicated three times on fiftieth-acre plats instead of being sown on a single tenth-acre plat. An earlier and a later date of seeding, August 6 and November 16, respectively, were added to the test. The seeding of September 16 was not made, because the soil was so dry that germination could not be obtained. Good stands were secured from the plats sown on each date. A view of the plats on October 24 is shown in figure 7. The earliest date of seeding produced the highest yield, 29.2 bushels.

Because of the variations from year to year, the difference in average yields obtained from the various dates of seeding was not great. If the plats sown October 1, 1909, had not failed to germinate, that date probably would have given the highest average yield for the four years when crops were produced. The next highest yield was from the plats sown October 16. For the three years, 1909, 1910, and 1913, the highest yield was from the August 16 seeding, with that of October 16 second.

The great variations in seasonal conditions make it difficult to decide the best date for seeding wheat in western South Dakota. If rains occur early and are fairly abundant, early seeding is probably best. It is not always possible to conserve sufficient moisture to insure germination; hence, it is not usually safe to sow in dry soil with the expectation of receiving sufficient rain for germination. The safest rule seems to be to have the ground ready for early seeding, so that the seed may be sown early or late as the conditions seem to indicate. The results obtained on the Belle Fourche Experiment Farm appear to show that sowing as late as November 1 will often give better yields than are obtained from spring wheat. Because the

FIG. 8.—The winter-wheat nursery on the Belle Fourche Experiment Farm in 1910.

current season's crop is often not thrashed and ready for sowing in August, it is desirable to carry over a supply of seed, so that the crop may be sown early if it appears to be desirable.

NURSERY EXPERIMENTS WITH WINTER WHEAT.

About 600 selected heads of Turkey, Kharkof, and Crimean wheats were sown in head rows in the fall of 1908. Practically all of these were sown in 60-foot rows the following year. As it seemed desirable to test the best of these selections in field plats as soon as possible, about 35 of them were sown in fiftieth-acre plats in the fall of 1910. Because of the extreme drought the next spring and summer no grain was produced. Enough seed was left from the 1909 crop, however, to sow in duplicate 60-foot rows in the fall of 1911. The seed did not germinate until the following spring, and the stand was then so thin that very low yields were obtained. The selections were again sown in duplicate rows in the fall of 1912, while a few of which there was sufficient seed were sown in fiftieth-acre plats. A view of the winter-wheat nursery in 1910 is shown in figure 8.

The average yields of the selections in duplicate 60-foot rows in 1910, 1912, and 1913 varied from 32 to 65.8 ounces. Most of the selections yielded between 48 and 60 ounces. A few beardless races which were selected proved to be particularly high in yield. The average yield of all nine beardless races was 56.2 ounces, while the nine best bearded races produced an average yield of 56 ounces. The best beardless race, selection No. 343, produced an average yield of 65.8 ounces, while the best bearded race yielded 61.4 ounces.

The beardless races sown in fiftieth-acre plats in 1910 appeared to be fully as resistant to drought as any of the bearded races. There appeared to be little difference in hardiness between the bearded and beardless strains, not only at Newell but also at three other field stations in the northern Great Plains where they were tested. The grain is very similar to that of the Turkey and Kharkof wheats in quality and appearance. Whether these beardless strains originated from mechanical mixtures of some beardless fall variety, such as Ghirka Winter, or from accidental hybrids between a bearded hard winter wheat and a beardless winter wheat was not determined.

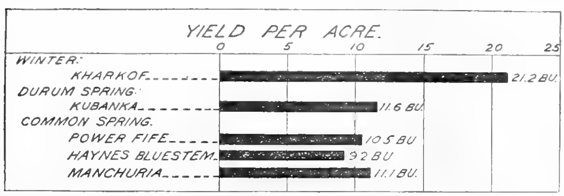

FIG. 9.—Diagram showing the average yields per acre, in bushels, of the best varieties of winter wheat and each group of spring wheat at the Belle Fourche Experiment Farm, for six years, 1908 to 1913, inclusive.

COMPARISON OF SPRING AND WINTER WHEATS.

A comparison of the yields of winter and spring wheat which have been obtained at Newell should be of interest and value. The annual and average yields of the best varieties of winter, of durum, and of common spring wheat are shown in Table XV. The average yields are also shown graphically in figure 9.

The yields of winter wheat in 1908 were slightly larger than those of the best durum wheats and exceeded by several bushels those of the spring common wheats. In 1909 the yields of winter wheat were nearly double those of the durum and more than double those of the spring common varieties. Again in 1910 the yields of winter wheat were double or more than double those of the spring varieties. In 1911 no yields of either spring or winter wheat were obtained, while in 1912 no grain was produced except by a few varieties of spring common wheat. In 1913 the yields of winter wheat were again about double those of durum and more than double those of the spring common wheats.

TABLE XV.—*Annual and average yields of the best varieties of winter and of durum and common spring wheats on the Belle Fourche Experiment Farm, 1908 to 1913, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).						
		1908	1909	1910	1911	1912	1913	Average.
Winter:								
Kharkof	1442	25.4	40.3	22.7	0	0	38.6	21.2
Spring durum:								
Kubanka	1516	23.8	22.6	5.3	0	0	19.1	11.8
Spring common:								
Manchuria	2492	16.2	16.0	12.8	0	4.5	17.1	11.1
Power	3025	18.5	17.3	10 6	0	0	16.6	10.5
Haynes	3020	18.3	13.8	9.0	0	0	14.1	9.2

To summarize: In three of the six years covered by the experiments the winter varieties have produced about double the yield obtained from the spring varieties. In one year the yield was only slightly larger and in two years practically all varieties of both spring and winter wheats were total failures. The average yield of the best winter variety for the six years was 21.2 bushels, while the average yield of the best durum variety was 11.8 bushels. Winter wheat is to be preferred to spring wheat, because the growing of a fall-sown grain allows a better distribution of labor throughout the year. Winter wheat also matures earlier and so is more likely to escape hailstorms, hot winds, and other unfavorable climatic conditions. On the other hand, sufficient moisture for germination is less likely to be available in the fall than in the spring, and there is also danger of damage to the crop from the blowing of the soil during the winter. Winterkilling has not been a factor of much importance in the experiments at Newell, nor is it likely to be if varieties of the Turkey group are grown. If a crop of winter wheat is lost because of the blowing of the soil, winterkilling, or other factors, there is still opportunity to sow the land to some spring crop. For these reasons the growing of winter rather than spring wheat is strongly recommended.

EXPERIMENTS WITH OATS.

The yields of oats which have been obtained at Newell have for the most part been unsatisfactory. In 1908, 1909, and 1913 fairly good yields were obtained, but in 1910 and 1912 the returns were less than the cost of production, while in 1911 a total failure was recorded.

The average yield of the best variety for the six years from 1908 to 1913 was only 19.4 bushels, which is less than the average yield of winter wheat for the same period. The yield of the best spring wheat for the six years was slightly less than 12 bushels to the acre, but the production in pounds is greater than that of oats and the value of the crop is also higher. For this reason the oat crop can not be recommended to the farmer on the dry lands in western South Dakota. If oats are grown, only the very earliest varieties, such as Sixty-Day and Kherson, should be used.

The experiments with oats at Newell have included varietal tests and a test of rate of seeding with Kherson oats.

VARIETAL TEST OF OATS.

The varietal experiments with oats during the six years from 1908 to 1913 have included 16 varieties and races. Of these, eight may be classed as early, five as midseason, and three as late varieties. All the late varieties are side oats, while all the early and midseason varieties have open or spreading panicles. Only five of the 16 varieties have been grown in all of the six years. The annual and average yields of the 16 varieties and races are given in Table XVI.

TABLE XVI.—*Annual and average yields of 16 varieties and races of oats on the Belle Fourche Experiment Farm, 1908 to 1913, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).							
		1908	1909	1910	1911	1912	1913	Average. 6 years, 1908–1913.	Average. 4 years, 1910–1913.
Early varieties:									
Burt	293					6.0	22.4		
Kherson	459	[a]47.5	[a]25.7	[a]15.0	0	6.2	21.9	19.3	10.8
Seventy-Five-Day	337					7.5	21.0		
Sixty-Day	165	[a]46.6	25.0	15.6	0	6.6	22.7	19.4	11.2
Sixty-Day selection	(165–562)					6.2			
Do	(165–566)					7.1	23.3		
Do	625			14.4	0	7.9	21.6		11.0
Do	626			16.6	0	9.9	24.6		12.8
Midseason varieties:									
Big Four	658		32.0	3.6	0	14.1	19.5		9.3
Canadian	444	38.8	21.3	4.4	0	10.4	18.5	15.6	8.3
Danish	441	36.1							
Great Dane			26.6						
Swedish Select	134	38.1	28.4	2.3	0	9.2	15.2	15.5	6.7
Late varieties:									
White Russian	551	30.9	20.0	0	0	22.7	14.3	14.6	9.2
White Tartarian	300	30.9	22.8	0	0				
Yellow Giant	342	19.4	17.5	0	0				

[a] Average of two plats.

Table XVI shows that fairly good yields of oats were obtained from all varieties in 1908, when the seasonal rainfall was slightly above normal and the distribution of the rainfall was favorable. The low yield in 1909 was due in large measure to poor preparation of the seed bed and resulting poor germination and slow growth. Abundant rainfall favored the larger and later varieties, such as Big Four and Swedish Select, which may always be expected to yield more than the early varieties in particularly favorable years. In 1910 the conditions early in the season were exceptionally good, but the rainfall after the seed germinated was much below normal and consequently only the earliest varieties produced yields which were worthy of consideration. In 1911 no yields were obtained from any of the varieties, because of the severe drought.

In 1912 there was little water stored in the soil, but the precipitation during the growing season was fairly favorable. On account of the dryness of the soil at seeding time the drill was run rather deeper than usual. Just after seeding a heavy rain caused the soil to pack and crust, so that the germination was low. This, in addition to the lack of stored water, caused the low yields which were obtained. The midseason and late varieties yielded better than the early varieties, for the reason that they were benefited by a heavy rain which fell early in July, too late to be of material help to the early varieties.

In 1913 the varietal test of oats was grown on land which produced a crop of corn in 1912. In all previous years the oats were grown on soil which had been fallowed. The corn land was not plowed but was disked and harrowed to make a good seed bed. The rainfall conditions were about normal and fair yields were obtained. As in previous years the earlier varieties produced the highest yields.

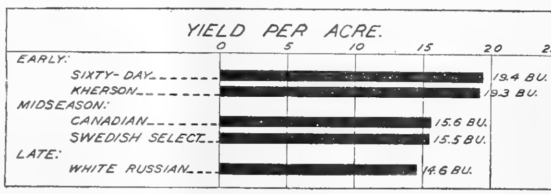

Fig. 10.—Diagram showing the average yields per acre, in bushels, of the leading varieties of oats at the Belle Fourche Experiment Farm, for six years, 1908 to 1913, inclusive.

In 1907 two plats of Boswell Winter oats, C. I. No. 480, were sown. Only a small percentage of the plants survived the winter, but these tillered so freely that a yield of 28.5 bushels per acre was obtained. This variety was again sown in 1908 and 1909, but winterkilled entirely each year.

LEADING VARIETIES OF OATS.

In Table XVII the average date of heading, date of ripening, weight per bushel, and yield per acre of grain and of straw are given for the five varieties which were grown during the entire period of six years. With the exception of the yield data, the averages are for five years (1908–1910, 1912, and 1913). The average yields of grain are shown graphically in figure 10.

The five varieties which have been grown for the entire six years at Newell, in the order of their average yield, are the Sixty-Day, Kherson, Canadian, Swedish Select, and White Russian. The pure-line selection of Sixty-Day, C. I. No. 626, which was added to the test in 1910, has given an average yield 1.6 bushels higher than the unselected Sixty-Day for the four years from 1910 to 1913.

The Sixty-Day and Kherson are very similar varieties, imported about 15 years ago from southern Russia. They are early in maturing, ripening at Newell about July 20. The straw is short and the grains small and yellow. They are the best varieties for growing on the dry farms in the Belle Fourche section.

TABLE XVII.—*Average dates of heading and maturity, weight per bushel, and yields of five leading varieties of oats on the Belle Fourche Experiment Farm, 1908 to 1913, inclusive.*

Group and variety.	C. I. No.	Date of—		Weight per bushel.	Yield per acre.	
		Heading.	Maturity.		Grain.	Straw.
				Pounds.	*Bushels.*	*Pounds.*
Early:						
Kherson	459	June 27	July 20	30.8	19.3	800
Sixty-Day	165	June 26	July 17	30.9	19.4	720
Midseason:						
Canadian	444	July 8	July 29	34.5	15.6	1,080
Swedish Select	134	July 9	Aug. 2	28.2	15.5	930
Late:						
White Russian	551	July 18	Aug. 8	30.4	14.6	1,040

The Canadian is a medium-early oat which has averaged 4 bushels less than the Sixty-Day and Kherson at Newell for the six years. The yield of straw, however, is greater. The heads are large and spreading, and the kernels are white, broad, and very short. This variety matures about 10 days later than the Kherson.

The Swedish Select is extensively grown in the more humid regions to the eastward, but it is rather too late for sowing in western South Dakota. This is a white oat with kernels of medium length, rather broad, and usually bearing a strong, black awn. It matures about five days later than the Canadian and about two weeks later than the Kherson and Sixty-Day.

The Big Four is quite similar to the Swedish Select except that the awns are few and weak. It has produced rather better yields than the Swedish Select at Newell each year since 1909, when it was added to the test. For the four years from 1910 to 1913 this variety was exceeded in average yield only by the Kherson and Sixty-Day and by two pure-line selections of the latter variety. It is apparently the best of the midseason and late varieties which have been included in the test.

White Russian is a late side oat, with long and rather slender white kernels. The average yield of this variety for the six years is slightly lower than that of the Swedish Select and Canadian. It matures about one week later than the Swedish Select and about three weeks later than the Kherson and Sixty-Day. It can not be recommended for growing in the Great Plains.

RATE-OF-SEEDING TEST OF OATS.

A rate-of-seeding test with oats was conducted on the Belle Fourche Experiment Farm in 1909, 1910, 1912, and 1913. In 1909 and 1910 the Kherson and in 1912 and 1913 the Sixty-Day varieties were used. Plats were sown at the rates of 4, 6, 8, and 10 pecks each year. In addition, the 2-peck rate was used in 1909 and the 12-peck in 1910, 1912, and 1913. The test was conducted on fallow land in 1909, 1910, and 1912, while in 1913 it was on land which produced corn the previous year. In 1909 and 1910 single tenth-acre plats were sown at each rate. In 1912 and 1913 the test was replicated, three fiftieth-acre plats being sown at each rate.

Table XVIII shows the annual and average yields obtained in the rate-of-seeding test with oats in 1909, 1910, 1912, and 1913.

TABLE XVIII.—*Annual and average yields of oats in a rate-of-seeding test on the Belle Fourche Experiment Farm in 1909, 1910, 1912, and 1913.*

[In 1909 and 1910 the variety used was the Kherson, C. I. No. 459. In 1912 and 1913 the Sixty-Day variety, C. I. No. 165, was used.]

Rate per acre.	Yield per acre (bushels).				
	1909	1910	1912	1913	Average.
2 pecks	25.9				
4 pecks	30.2	11.9	8.9	28.2	19.8
6 pecks	32.8	12.5	10.3	27.3	20.7
8 pecks	35.3	10.3	9.2	27.3	20.5
10 pecks	35.9	4.1	9.7	28.1	19.5
12 pecks		3.4	9.1	28.2	

In 1909, which was a favorable year, the higher rates of seeding gave the better yields, though the differences between the 6, 8, and 10 peck rates were small. In 1910, a very dry year, the best yields were obtained from the 4-peck and 6-peck rates. The yields obtained from the 10-peck and 12-peck rates of seeding little more than equaled the quantity of seed which was sown. In 1912, another dry year, there was little variation in the yields which were obtained, though the 6-peck rate produced slightly more than any of the others. In 1913, a favorable year, the yields obtained from all the rates of seeding were practically the same.

The average yield for the four years from the 4, 6, 8, and 10 peck rates shows little variation, though the figures favor slightly the 6-peck rate. The thickly sown plats ripened earlier than those sown at the lower rates, while the yield of straw was usually less. In very dry years thin seeding is to be preferred. On the other hand, in favorable seasons fully as good yields and slightly earlier maturity will be obtained from thick seeding. It seems probable that 6 pecks is about the best rate for early varieties, such as the Sixty-Day and Kherson.

NURSERY EXPERIMENTS WITH OATS.

About 100 heads each of the Sixty-Day and Kherson oats were selected in 1908 and grown in head rows in 1909. In addition a number of selections of the Sixty-Day made at the Highmore substation, Highmore, S. Dak., were grown in head rows in 1908 and in duplicate 60-foot rows in 1909. The most promising of the Highmore selections were grown in duplicate fiftieth-acre plats in 1910, while the remainder of these and the progeny of the 1909 head rows were grown in 60-foot rows. In 1912 and 1913 the best of these selections were grown either in plats or in replicated 60-foot rows.

Two of these selections, Nos. 562 and 566, were grown in the regular varietal test in 1912, where they produced about the same yields as the unselected Sixty-Day. Selection No. 566 was again grown in 1913, when it slightly exceeded in yield the parent variety. None of the selections which have been made at Newell from the Sixty-Day and Kherson varieties appears to be particularly better than the original unselected stocks.

EXPERIMENTS WITH BARLEY.

Barley is quite an important crop in the northern Great Plains, because of its early maturity, its comparatively low water requirement, and the feeding and market value of the grain. The varietal test at Newell has included the principal varieties that have given good results elsewhere in the northern Great Plains. On the whole, the results which have been obtained are decidedly disappointing. From the results here reported, barley can not be recommended for the Belle Fourche section.

VARIETAL TEST OF BARLEY.

The varietal test has included five strains of 6-rowed hulled, two of 6-rowed naked, and five of 2-rowed hulled barley during the six years. Only two of the varieties were grown in all of the six years, while six were grown in the five years from 1909 to 1913. The annual and average yields of all the varieties from 1908 to 1913 are shown in Table XIX.

In 1908 two lots of Hanna barley, one of Manchuria, and two of Nepal were grown. The highest yields were obtained from the Hanna, a 2-rowed hulled variety. The yields from both the 2-rowed and 6-rowed hulled varieties were fairly satisfactory. Two varieties of winter barley which were sown in the fall of 1907 entirely winter-killed.

In 1909 four 2-rowed hulled, three 6-rowed hulled, and two 6-rowed naked varieties were grown. The hulled varieties yielded from 17.3 to 23.8 bushels per acre, while the naked varieties yielded about 9 bushels each. The highest yield was again obtained from the Hanna, C. I. No. 24.

The same varieties were grown in 1910. Because of the extreme drought only the very earliest varieties matured grain, and the crop obtained even from these was very small. The Odessa, an early

6-rowed variety, produced the highest yield, 8.1 bushels. The yields obtained from the 6-rowed naked and the 2-rowed hulled varieties were not sufficient to pay for the cost of harvesting. All the varieties were a total failure in 1911.

TABLE XIX.—*Annual and average yields of 12 varieties of barley on the Belle Fourche Experiment Farm, 1908 to 1913, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).								
		1908	1909	1910	1911	1912	1913	Average.		
								6 years, 1908–1913.	5 years, 1909–1913.	2 years, 1912–1913.
Six-rowed hulled:										
Gatami	575					18.3	8.2			13.2
Manchuria (Minn. No. 105)	354					7.6	6.6			
Manchuria (Minn. No.6)	638		19.8	5.2	0	8.1	8.0		8.2	8.0
Manchuria	643	26.0	17.3	4.3	0	7.2				
Odessa	182		22.1	8.1	0	9.8	8.7		9.7	9.2
Six-rowed naked:										
Nepal (White Hull-less)	262	16.3	9.6	2.5	0					
Do		12.0	9.0	1.7	0	10.7	8.9	7.0	6.1	9.8
Two-rowed hulled:										
Chevalier II	530		22.1	0	0	0	6.8		5.8	3.4
Hanna	24	29.0	[a]23.8	[a]1.0	0	0	10.7	10.7	7.1	5.3
Do	203	27.9	21.4	1.4	0	0				
Hannchen	531		19.2	3.1	0	0	12.7		7.0	6.3
White Smyrna (Ouchac)	658					10.7	14.3			12.5

[a] Average of 2 plats.

In 1912 ten of the twelve varieties which were included in the test were grown in fiftieth-acre plats replicated five times. The other two varieties were grown in single plats, as there was not sufficient seed for the replications. The soil in which the test was conducted had in previous seasons appeared to be very uniform, but the growth and yield of the barley varieties in 1912 showed great variation. This was perhaps due to the drifting of the snow on the plats during the previous winter, as the rainfall was extremely low in 1912 and slight differences in moisture content were likely to cause considerable variations in yield. Many of the plats produced no grain and others matured seed only along the borders. The only variety of which all plats were harvested was the Gatami, an early black 6-rowed variety, which was grown for the first time at Newell in 1912. The yield of this variety was 18.3 bushels to the acre.

In 1913 the barley varieties were grown on land upon which a small crop of spring wheat was produced the previous year. The soil was in excellent condition at the time of seeding, and germination and growth were prompt and vigorous. The rainfall during June and July was slight, so that all the varieties were injured by drought. A hailstorm which occurred just as the earlier varieties were heading severely injured the Gatami and did some damage to the Manchuria and Odessa varieties. The highest yields in 1913 were produced by the 2-rowed barleys, though it is probable that the Gatami and the other 6-rowed varieties would have yielded more than any of the 2-rowed barleys if they had not been injured by hail.

Only the Hanna, C. I. No. 24, and the Nepal have been grown for the entire six years. The average yield of the Hanna for that period was 10.7 bushels, and of the Nepal, 7 bushels. Six varieties have been grown for the five years from 1909 to 1913. Of these, the highest yield, 9.7 bushels, was produced by the Odessa, a medium-early 6-rowed variety. The Manchuria (Minnesota No. 6) averaged 8.2 bushels for this period and the Hanna and Hannchen about 7 bushels each. The average yields of these varieties are shown graphically in figure 11.

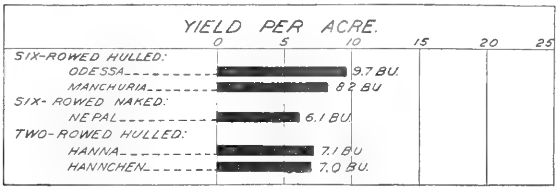

FIG. 11.—Diagram showing the average yields per acre, in bushels, of the leading varieties of barley at the Belle Fourche Experiment Farm, for five years, 1909 to 1913, inclusive.

LEADING VARIETIES OF BARLEY.

The average date of heading and of maturity, weight per bushel, and the yield of grain and of straw for the leading varieties of barley grown at Newell are given in Table XX.

TABLE XX.—*Average dates of heading and of maturity, weight per bushel, and yields of the seven leading varieties of barley on the Belle Fourche Experiment Farm, 1909 to 1913, inclusive.*

Group and variety.	C. I. No.	Date of—		Weight per bushel.	Yield per acre.	
		Heading.	Maturity.		Grain.	Straw.
				Lbs.	*Bush.*	*Lbs.*
Six-rowed hulled:						
Gatami	575	June 25 [a]	July 14 [a]	[a] 45.1	[a] 13.2	[a] 870
Odessa	182	June 26 [b]	...do [b]...	[b] 45.5	9.7	760
Manchuria (Minn. No. 6)	638	June 30 [b]	July 18 [b]	[b] 44.3	8.2	600
Two-rowed hulled:						
White Smyrna (Ouchac)	658	....	July 15 [a]	[a] 42.4	[a] 12.5	[a] 940
Hanna	24	July 3 [c]	July 22 [d]	[d] 46.9	7.1	750
Hannchen	531	...do [c]...	July 18 [d]	[d] 46.9	7.0	640
Six-rowed naked:						
Nepal	....	June 28 [b]	July 20 [b]	[b] 58.6	6.1	590

[a] Two-year average, 1912 and 1913.
[b] Four-year average, 1909, 1910, 1912, and 1913.
[c] 1909 only; heads not fully exserted in 1910, 1912, and 1913.
[d] Three-year average, 1909, 1910, and 1913; failure in 1911 and 1912.

The Odessa, C. I. No. 182, a 6-rowed bearded hulled barley, has given the highest average yield at Newell for the five years from 1909 to 1913. This variety is early in maturing, ripening at Newell about a week before the Hanna and four or five days earlier than the Manchuria. It was introduced from southern Russia, where it is grown in the same region as the Sixty-Day and Kherson oats. It is recommended as one of the best varieties of barley for western South Dakota.

The Gatami, C. I. No. 575, has been grown at Newell only in 1912 and 1913. In 1912 it yielded 18.3 bushels to the acre, nearly double the yield obtained from any other variety. In 1913 it was exceeded in yield by several varieties. Its average yield for the two years is 4 bushels greater than that of the Odessa for the same period. The Gatami matures a little earlier than the Odessa, and for that reason is to be preferred to it. The grain, however, is black and hence is lower in market value than the Odessa and other light-colored barleys.

The Manchuria (Minnesota No. 6), C. I. No. 638, is the 6-rowed bearded barley commonly grown in Minnesota and Wisconsin. It is several days later in maturing than the Gatami and Odessa, and its average yield for the five years from 1909 to 1913 is 1½ bushels less than that of the Odessa. It can not be recommended for western South Dakota.

FIG. 12.—Plat of Hanna barley on the Belle Fourche Experiment Farm, 1910.

The Hanna and Hannchen are 2-rowed bearded hulled barleys which yielded well in 1909 and 1913. The Hanna was also grown in 1908, when it produced the highest yield of any variety included in the test. The Hanna and Hannchen matured no grain in 1911 and 1912 and only a very small crop in 1910, so that their average yields for the five years from 1909 to 1913 were only 7.1 and 7 bushels per acre, respectively. This is more than 2½ bushels less than the average yield of the Odessa for the same period. These 2-rowed barleys are a week to ten days later in maturing than the Odessa and the Gatami, and ordinarily they mature later than the Manchuria. At Newell they have usually ripened prematurely, so that the length of their growing season there is below the normal. A field of Hanna barley on the experiment farm in 1910 is shown in figure 12.

The White Smyrna, C. I. No. 658, an early 2-rowed barley, was grown at Newell only in 1912 and 1913. In 1912 it was exceeded in yield only by the Gatami, while in 1913 it produced the highest yield of any variety in the test. The average yield for the two years is 12.5 bushels, only 0.7 bushel less than that of Gatami and higher than that of any other variety. If a 2-rowed variety of barley is to be grown in western South Dakota, it is probable that the White Smyrna or some similar one should be selected.

The yields obtained from the Nepal (White Hull-less), a 6-rowed naked variety, have been less than those from any of the hulled varieties, except in 1912 and 1913. In these years the Nepal produced less than the best hulled varieties.

EXPERIMENTS WITH MINOR CEREALS.

RYE.

Winter rye has been grown in field plats at Newell for only one year, 1913. Three plats produced an average yield of 5.3 bushels, as compared with a yield of 38.8 bushels of Kharkof winter wheat on a near-by plat The low yield of the rye was in part due to damage from a hailstorm, which occurred after the rye headed but before the wheat was far enough advanced to be injured. Another reason for the low yield was that a large percentage of the florets failed to set seed, probably because the pollen was injured by high temperatures, low humidity, or some other unfavorable climatic condition.

EMMER.

Spring emmer, C. I. No. 1524, has been grown each year with the series of barley varieties, as it was considered that emmer is comparable to barley as a feed grain. The yields obtained were as follows: 1908, 31.8 bushels; 1909, 21.7 bushels; 1910, 0.3 bushel; and 1913, 11.1 bushels. No yields were produced in 1911 and 1912. The average yield for the six years was 10.8 bushels, while the yield of Hanna barley for the same period was 10.7 bushels. For the five years from 1909 to 1913 the average yield was only 6.6 bushels, as compared with 9.7 bushels for the Odessa barley. For the same period, Sixty-Day oats yielded 14.0 bushels and Kubanka durum wheat 9.4 bushels. These yields are equivalent to 211 pounds of emmer, 466 of barley, 448 of oats, and 564 of wheat.

Black Winter emmer, C. I. No. 2337, was sown in the fall of 1908. It is estimated that only 1 per cent of the plants survived the winter. This crop was not grown again until the fall of 1912, when a plat of Buffum Improved winter emmer, C. I. No. 3331, was sown. This variety yielded 1,035 pounds of grain, as compared with 2,130 pounds of winter wheat on a near-by plat.

The few tests of emmer which have been made at Newell indicate that the crop is not one which can be recommended for that section.

EXPERIMENTS WITH FLAX.

VARIETAL TEST.

A varietal test of flax was begun at Newell in 1912, when nine varieties were grown. Only five of these were grown in 1913. In 1912 flax was grown on land which was fallow the previous year and in 1913 on land which produced a crop of small grain in 1912. The annual and average yields of grain and of straw for the five varieties are shown in Table XXI.

TABLE XXI.—*Annual and average yields of five varieties of flax on the Belle Fourche Experiment Farm in 1912 and 1913.*

C. I. No.	Variety.	1912		1913		Average.	
		Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
		Bushels.	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*
12	Primost (Minn. No. 25)	9.1	880	4.8	910	7.0	895
19	Russian (N. Dak. No. 155)	8.9	730	5.2	830	7.1	780
7	Smyrna	11.4	880	2.8	710	7.1	795
1	Select Russian (N. Dak. No. 608)	10.6	1,130	3.3	630	7.0	880
3	Select Russian (N. Dak. No. 1215)	11.2	940	5.6	910	8.4	925

The highest average yield of flax obtained on the Belle Fourche Experiment Farm, 8.4 bushels per acre, as shown in Table XXI, was produced by the Select Russian, C. I. No. 3. This variety produced the highest yield in 1913 and was only slightly exceeded by one other variety in 1912. C. I. No. 3 is a pedigreed strain from the North Dakota Agricultural Experiment Station, being North Dakota No. 1215. The yields of the four other varieties which were tested both years were practically the same, being 1.3 or 1.4 bushels less than that of C. I. No. 3.

DATE-OF-SEEDING TEST OF FLAX.

A date-of-seeding test with Primost (Minnesota No. 25) flax was conducted at Newell in 1912 and 1913. Fiftieth-acre plats replicated three times were sown on each of two dates, May 15 and June 1, in 1912, and on three dates, May 2, May 23, and June 9, in 1913. The yields of grain and of straw and the weight per bushel of the grain from the various dates of seeding are shown in Table XXII.

The highest yield in 1912 was obtained from the later date of seeding, June 1. The increase in yield over the sowing made May 15 was about 25 per cent. The earlier sown plats were injured by drought to a greater extent than the plats sown on June 1. In 1913 this condition was reversed. The highest yield was produced from the earliest sown plats and the injury from drought increased with the later dates of seeding. It is probable that the best results will be obtained in western South Dakota if flax is sown at the earliest date when good germination and growth may be expected.

TABLE XXII.—*Yields of flax and weight of seed per bushel in a date-of-seeding test on the Belle Fourche Experiment Farm in 1912 and 1913.*

Date of seeding.	Yield.		Weight of seed per bushel.
	Grain.	Straw.	
1912.	*Bushels.*	*Pounds.*	*Pounds.*
May 15	8.3	1,020	55.0
June 1	10.6	1,860	54.3
1913.			
May 2	7.7	1,110	54.8
May 23	4.8	830	55.0
June 9	3.0	530	53.7

SUMMARY.

The experiments here reported were conducted on unirrigated land on the Belle Fourche Reclamation Project at Newell, S. Dak., from 1908 to 1913.

The results obtained at Newell are believed to be applicable in general to western South Dakota, northeastern Wyoming, and southeastern Montana.

The experiments were conducted on a heavy, impervious clay soil known as Pierre clay. This soil is quite typical of the locality.

The average precipitation during the six years was 13.41 inches. The average precipitation during the growing season for small grains, March to July, inclusive, was 7.76 inches. The minimum precipitation for the growing season and for the year was recorded in 1911.

On the average, satisfactory yields were obtained from winter wheat and fairly good yields from spring wheat. The returns from spring oats, barley, and emmer and from winter rye and emmer have not been sufficient to make these crops profitable. Total or almost total failures of all crops were recorded in 1911 and 1912.

The best average yields of spring wheat have been obtained from the durum varieties, Kubanka and Arnautka. Of the spring common wheats, the best variety to grow appears to be the Power Fife.

The best rate of seeding for durum wheat is from 4 to 5 pecks to the acre and for spring common wheat from 3 to 4 pecks.

The best varieties of winter wheat for western South Dakota are the Kharkof, Turkey, and Crimean. These are very similar varieties, which differ only slightly in value.

Experiments to determine the best date of seeding for winter wheat have failed to show any definite results. In general, the date of seeding must be determined by the seasonal conditions. Medium early seeding is to be preferred if there is sufficient moisture to insure germination.

It is much better to grow winter wheat than spring wheat in the Belle Fourche section. The average yield of Kharkof winter wheat for the six years was 21.2 bushels, of the best durum 11.8 bushels, and of the best spring common 11.1 bushels.

The best average yields of oats for the six years were obtained from the Sixty-Day and Kherson varieties. The returns from this crop were much lower than from winter wheat and slightly lower than from spring wheat.

The best rate of seeding for small-kerneled early varieties of oats, such as the Sixty-Day and Kherson, is about 6 pecks to the acre.

The returns from barley were even less satisfactory than those from oats. The best average yield for the six years was only 10.7 bushels, and for the five years from 1909 to 1913, only 9.7 bushels. The most satisfactory varieties are those which mature early, such as the 6-rowed varieties, Gatami and Odessa, and the 2-rowed variety, White Smyrna.

The yields obtained from winter rye and from winter and spring emmer have been much lower than those from the other cereals. These crops can not now be recommended for western South Dakota.

The best yield from flax in a 2-year test was obtained from the Select Russian variety. It is probable that the best results will be obtained if this crop is sown as early as good germination and growth may be expected.

The following varieties are recommended for the Belle Fourche section:

Winter wheat.—Kharkof, Turkey, Crimean.
Spring wheat.—Kubanka durum, Arnautka durum, Power Fife, Marquis.
Oats.—Sixty-Day, Kherson.
Barley.—Odessa, Gatami, White Smyrna.

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Oats: Distribution and Uses. Farmers' Bulletin 420.

Oats: Growing the Crop. Farmers' Bulletin 424.

Barley: Growing the Crop. Farmers' Bulletin 443.

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Winter-Wheat Varieties for the Eastern United States. Farmers' Bulletin 616.

Growing Hard Spring Wheat. Farmers' Bulletin 678.

Varieties of Hard Spring Wheat. Farmers' Bulletin 680.

Winter Wheat in Western South Dakota. Bureau of Plant Industry Circular 79.

Hard Wheats Winning Their Way. Separate 649, Yearbook, 1914.

The Work of the Belle Fourche Experiment Farm in 1912. Miscellaneous Papers. Bureau of Plant Industry, Circular 119.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 298

Contribution from Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C. August 31, 1915.

PEACH SUPPLY AND DISTRIBUTION IN 1914.[1]

By WELLS A. SHERMAN, *Specialist in Market Surveys;* HOUSTON F. WALKER, *Scientific Assistant;* L. HERBERT MARTIN, *Assistant in Market Surveys.*

CONTENTS.

INTRODUCTION.

Peaches, being among the most highly perishable crops, present many difficult marketing problems. A large part of the crop must be transported over long distances to find profitable markets, being handled under refrigeration in insulated cars especially constructed for the transportation of perishable commodities.

In many sections large orchards have been planted and careful study has been given to the best methods of propagation, pruning, cultivation, and general care of the trees, so that there are perhaps few crops to which more scientific methods are applied so far as production is concerned.[2]

Much attention recently has been given in certain sections to grading and packing, but in most localities these two essentials in the successful marketing of peaches are not receiving the attention they deserve. All growers should realize the importance of taking the greatest care in the preparation of this crop for market. When the

[1] About 95 per cent of the reports of shipments listed in this publication were furnished by railroad officials, to whom grateful acknowledgment is made for their courtesy and assistance.

[2] Gould, H. P. Growing Peaches: Sites, propagation, planting, tillage, and maintenance of soil fertility. (Farmers' Bulletin 631.) Growing Peaches: Pruning, renewal of tops, thinning, interplanted crops, and special practices. (Farmers' Bulletin 632.)

NOTE.—This bulletin is of general interest to peach growers, shippers, dealers, transportation companies, and consumers.

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grading is carefully performed and the packing is standardized and rigidly inspected, peaches will be much more profitably marketed in almost all cases.

Most of the crop is marketed in containers holding from one-third to 1 bushel, the size and kind of container varying with the section of the country from which the peaches are shipped. In the West the peach box holding approximately 20 pounds is used; in the Southwest the four-basket crate, six-basket crate, and bushel basket; in the Central States Climax baskets, half-bushel and bushel baskets; and in the East and South six-basket carriers, half-bushel and bushel baskets.

The large number of varieties of peaches that may be grown successfully in some sections tends to prolong the period within which they can be marketed profitably. By planting a proper assortment of varieties the peach season in any particular locality can be extended somewhat, but as the picking season for any one variety is very short and as the principal commercial orchards are planted largely to Elbertas the commercial shipping season in these districts is very short in proportion to the large percentage of the total crop which they produce.[1]

The peach, on account of its very perishable nature, must be marketed as soon as possible after reaching maturity; therefore, the proper dispatch and distribution present many difficulties. Peaches will not stand delay, even when graded, packed, and handled in the best possible manner. If the grower of apples is not satisfied with the price offered at the time of harvest, he can store certain varieties until the following spring, when prices may be better. Peaches, on the other hand, must be disposed of immediately. If not already sold when loaded on the cars they must be started at once toward the market, and if they are not sold while en route it is important that they go to a market not already overstocked. An oversupply may occur in one market meaning heavy losses to certain growers, while at the same time consumers may be paying high prices in other localities. It is probable that many smaller towns could serve as carload distributing points if local dealers in these towns would cooperate in buying peaches by the carload and in pushing their sale.

The problem of peach marketing is one of irregular production and of unsatisfactory preparation and distribution rather than of overproduction. The increased consumption of California oranges made possible by effective distribution is an example of results accruing from care in the marketing of a crop of which there is a comparatively uniform supply.

[1] Gould, H. P. Growing Peaches: Varieties and classification. (Farmers' Bulletin 633.)

PRELIMINARY INQUIRY.

Previous to the marketing of the 1914 crop inquiries were sent out by the Office of Markets and Rural Organization to station agents at all points from which peaches were believed to be shipped in full carloads, and also to every cooperative organization listed by the department. These letters asked for a record of the actual number of carloads shipped in 1913, an estimate of the probable shipments in 1914, lists of important growers and shippers of peaches, the extent of the peach-shipping season in each district, and other information bearing on this subject.

Numerous data were gathered regarding the movement of the 1913 crop, the information being summarized from these inquiries and from many letters which were written to develop certain special features that arose during their tabulation. Only very general results of this investigation were made public, as it was felt that it was not sufficiently complete to warrant a separate publication.

SECOND INQUIRY—SOURCES OF INFORMATION.

After the shipping season of 1914 the inquiry was renewed. In addition to the sources already mentioned, the general railroad officials and others known to be interested largely in peach distribution were consulted. As a result this office has received definite reports on the shipments during 1914 from 993 shipping points at which peaches originate in car lots and a statement from the transportation and shipping agencies as to the number of carloads shipped from nearly all of these stations in that year.

It is somewhat difficult to obtain a statement of shipments in many localities. This is particularly true in territory surrounding the lakes and bays, where many of the shipments are made by boat to markets located comparatively near to point of origin. It has been found extremely difficult to get a statement from the many small boat lines which handle considerable quantities. In fact, with the facilities at hand it seems impossible to secure complete and accurate records for this class of business. Catawba Island, Ohio, is an important commercial peach section, and all the shipments are made by boat. Many shipments to Portland, Oreg., also are carried by boat. So far as possible, these figures have been obtained and reduced to equivalent carloads.

THE SHIPPING SEASON.

The peach season, when considered for the whole United States, extends from the middle of May, when shipments begin in Florida, to the latter part of October, when they end in the northern States. California, with its diversified climate and great number of varieties of peaches, probably has the longest season, i. e., from the middle of May to the end of September. The following diagram (fig. 1) shows

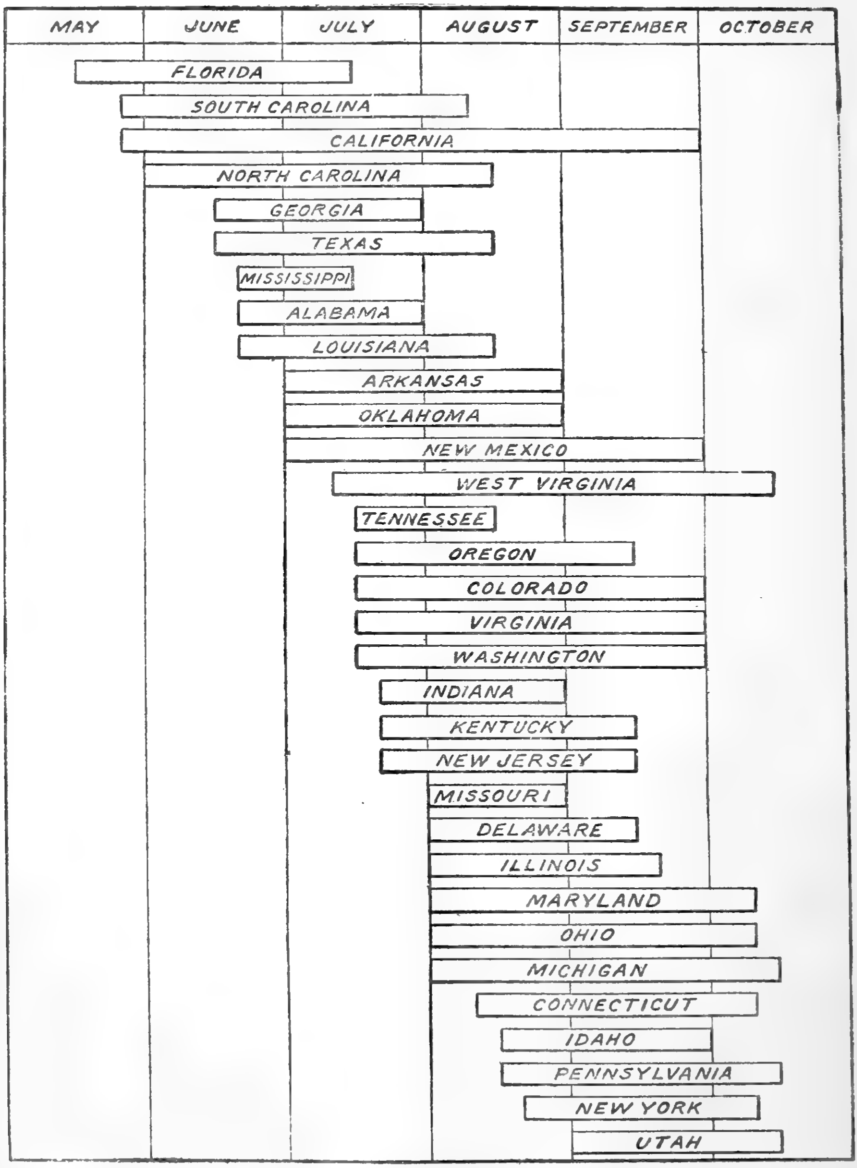


FIG. 1.—Peach-shipping season.

in detail the comparative shipping seasons of the different States. On the opposite page will be found a diagram (fig. 2) showing the comparative volume of shipments from the leading areas.

AREAS OF COMMERCIAL PRODUCTION.

A glance at the map (fig. 3) shows that the use of State names to designate commercial peach areas is often misleading. In certain cases it leads to useless subdivision of a single continuous producing area. Such is the case when we speak of the West Virginia, Maryland, and Pennsylvania peach areas separately, for the bulk of the shipments from these three States comes from a few contiguous counties forming a rather compact producing area extending from northeastern West Virginia through western Maryland and southern Pennsylvania.

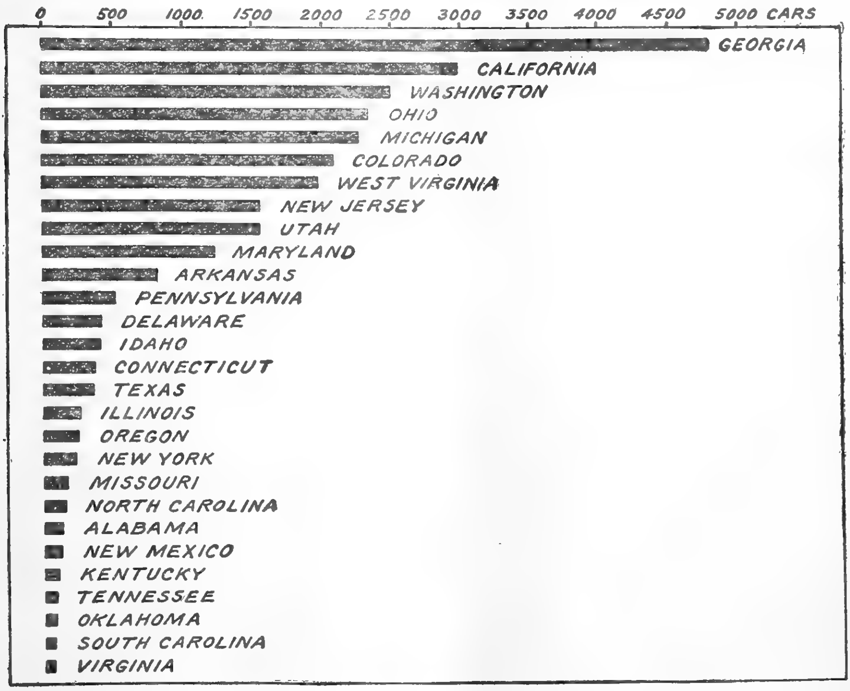


FIG. 2.—Relative bulk of peach shipments in 1914.

This area could be accurately referred to either as the Central Appalachian or Eastern Mountain district.

There is no geographical nor economic reason for distinguishing the shipments of central Alabama, central Georgia, and South Carolina by their respective State names. The greater part of the commercial crop of these three States is produced in what is essentially a single commercial area. North Georgia and southeastern Tennessee constitute a rather distinct district with somewhat later shipping dates, which, geographically, should be known as the Southern Appalachian or Southern Mountain district.

Delaware and New Jersey peaches are properly so called, since the shipping district in each case covers a large part of the State. Commercially, however, they constitute essentially one crop, all produced under similar climatic conditions and naturally supplying the same markets.

The Michigan, Ohio, and New York peach-shipping regions could be more accurately described as the Lake Michigan, Lake Erie, and Lake Ontario districts. In each case heavy shipments originate chiefly in a narrow belt close to the lake and are confined to a very small part of the agricultural area of the State.

Missouri peaches are not essentially different from the bulk of the Arkansas and a part of the Oklahoma crop. Most of the shipments of the three States could fairly be called Ozark peaches. Texas has a distinct shipping area in a region of lower altitudes and earlier season.

Colorado as a whole is not a peach State. It has an important shipping area, but it is almost wholly confined to two counties.

If the commercial movement of the peach crop of the country is to be reported daily with a degree of accuracy which will assist materially in its distribution and marketing, the chief shipping areas should be grouped somewhat as follows:

(1) Southeastern—Including the Carolinas, Georgia, Florida, Alabama, and eastern Tennessee.
(2) Southwestern—Including Texas, Louisiana, Arkansas, Oklahoma, and Missouri.
(3) Eastern—Including Virginia, West Virginia, Maryland, Pennsylvania, Delaware, New Jersey, and Connecticut.
(4) New York.
(5) Lake districts—Michigan and Ohio.
(6) Mountain districts—Colorado, Utah, and New Mexico.
(7) California.
(8) Northwestern—Including Washington, Oregon, and Idaho.

It would be logical to include New York shipments in the Lake district, but the trade is accustomed to think of the New York crop as a separate unit in the national supply.

The suggested grouping provides for practically all car-lot movement except from a few localities of minor importance in Kentucky, western Tennessee, southern Illinois, Indiana, Ohio, and West Virginia. These points might constitute a ninth group—the Ohio Valley.

PRESENTATION OF THE DATA.

The tabulated statement which is placed at the end of the bulletin shows the peach-shipping stations, and the number of cars reported as shipped from each point during the 1914 season, classified by States and to some extent by shipping districts. No attempt has been made to list stations where no full car lots originate. At those stations where full cars do originate the less than car-lot shipments have been ascertained so far as possible and reduced to equivalent carloads, and are included in the figures shown. Some of these stations this year did not ship in full carloads. However, if they usually are carload shipping points, they are still listed, and the amount shipped is less than car lots has been inserted.

Certain stations which are ordinarily car-lot shipping points are listed, although because of a failure of the crop no peaches were shipped therefrom in 1914. As the peach crop often suffers from extreme cold in the winter, or from frosts and other weather conditions in the spring and summer, the shipments from large districts may vary greatly from year to year. There are also certain producing areas where many trees are beginning to come into bearing, and this has a tendency to increase the shipments year by year. For these reasons, the figures given for any particular point in 1914 may be either much above or much below the average shipments, and this office has no authentic figures for the several preceding years which can be used by way of comparison.

No attempt has been made to secure figures for peaches supplied to neighboring markets by trucks or other similar conveyances, and while it is recognized that large quantities are thus conveyed to market, it is believed that these may be considered as purely for local use.

WORK UNDER WAY.

A survey of this character presents many difficulties and the department will gladly receive any suggestions in order that future publications may be more complete. This compilation, the map showing graphically the location of the important peach-shipping areas, and the approximate date for shipments have been verified as far as possible with the facilities at hand. It is believed to be the most comprehensive statement of the commercial peach crop that has been attempted, and is published with a belief that it will be found immediately useful in marketing the peach crop in 1915.

PRINCIPAL SHIPPING STATES.

The 10 leading States in the shipment of peaches in 1914, each showing shipments of more than 1,000 carloads, were as follows:

Shipment of peaches in 1914 by 10 leading States.

State.	Carloads.	State.	Carloads.
Georgia	4,803	Colorado	2,075
California	2,983	West Virginia	1,978
Washington	2,501	New Jersey	1,556
Ohio	2,340	Utah	1,556
Michigan	2,266	Maryland	1,231

EXPLANATION OF MAP.

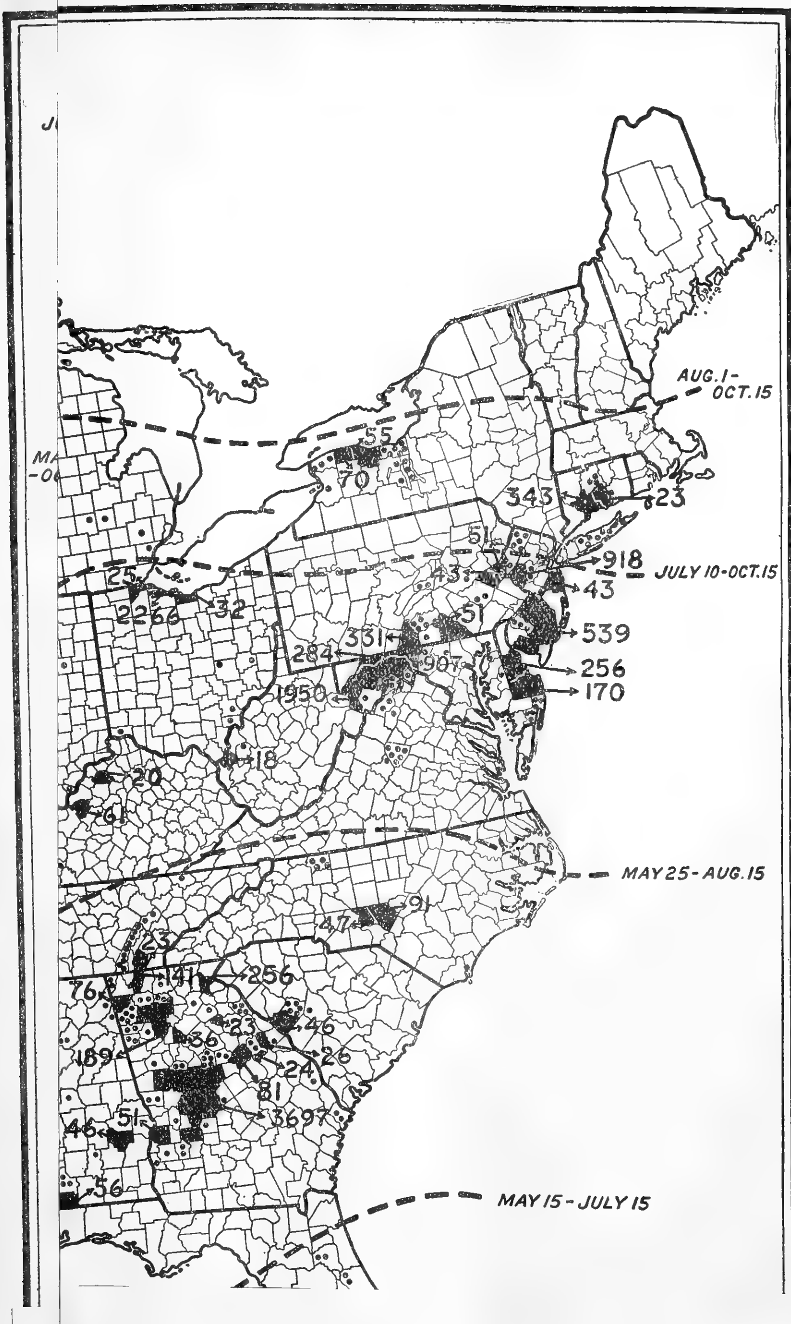
The accompanying map (fig. 3) indicates the reported actual carload shipments of peaches in the season of 1914. Each dot represents from 1 to 5 cars. For example, a county having two dots shipped from 6 to 10 cars, and one having 20 dots from 96 to 100 cars. Mechanical difficulties have necessitated the grouping of the dots in the county in which the shipping stations are located, although county lines are of no significance as boundaries for shipping areas. In cases where shipments are too heavy to be represented by dots, the counties have been blacked in and the actual number of cars shipped are given in figures. The size of the blackened area is not directly in proportion to the quantity shipped, and in order to make exact comparisons the tabulation by stations should be consulted.

The reported dates within which the various areas ship are shown by curved lines, all areas shipping at a given period being grouped in a zone under a line representing that period. The map in this way shows the various competing areas as well as the dates of heaviest crop movement, although these dates are subject to considerable seasonal variation.

PROSPECTIVE SHIPMENTS FOR 1915.

Early in the season of 1915, or after the bloom had dropped and the crop had set, estimates were secured of the prospective car-lot shipments for 1915 from 571 shipping points in 28 States. In every case the estimate was furnished by an official of a shipping organization, by a prominent grower, or by some one specifically interested in the crop. The total shipments from these 571 stations in 1914 were 22,877 cars. The estimates made indicated a total of 43,623 cars in prospect for 1915, or an increase of 90 per cent. These figures are not presented in detail because "June drops" reduced the prospective crop of certain districts while later condition reports to the department indicate that the shipments will not be as heavy as expected in other localities. The fact remains, however, that as this bulletin goes to press it is apparent that no important shipping area, except Colorado, will have a notably decreased output compared with last year, while many important districts will have very greatly increased shipments. This is notably true of the Southwest as a whole, of New York, and of the eastern mountain section.

The Bureau of Crop Estimates reported the condition of the peach crop of the entire United States on July 1 at 73.1 per cent of a normal, as compared with a 10-year average July 1 condition of 56.1 per cent of normal; from which figures a production forecast is made of 58,328,000 bushels this year, compared with a final estimate last year of 54,109,000 bushels.



AUG. 1-
OCT. 15
JULY 10-OCT. 15
MAY 25 - AUG. 15
MAY 15 - JULY 15
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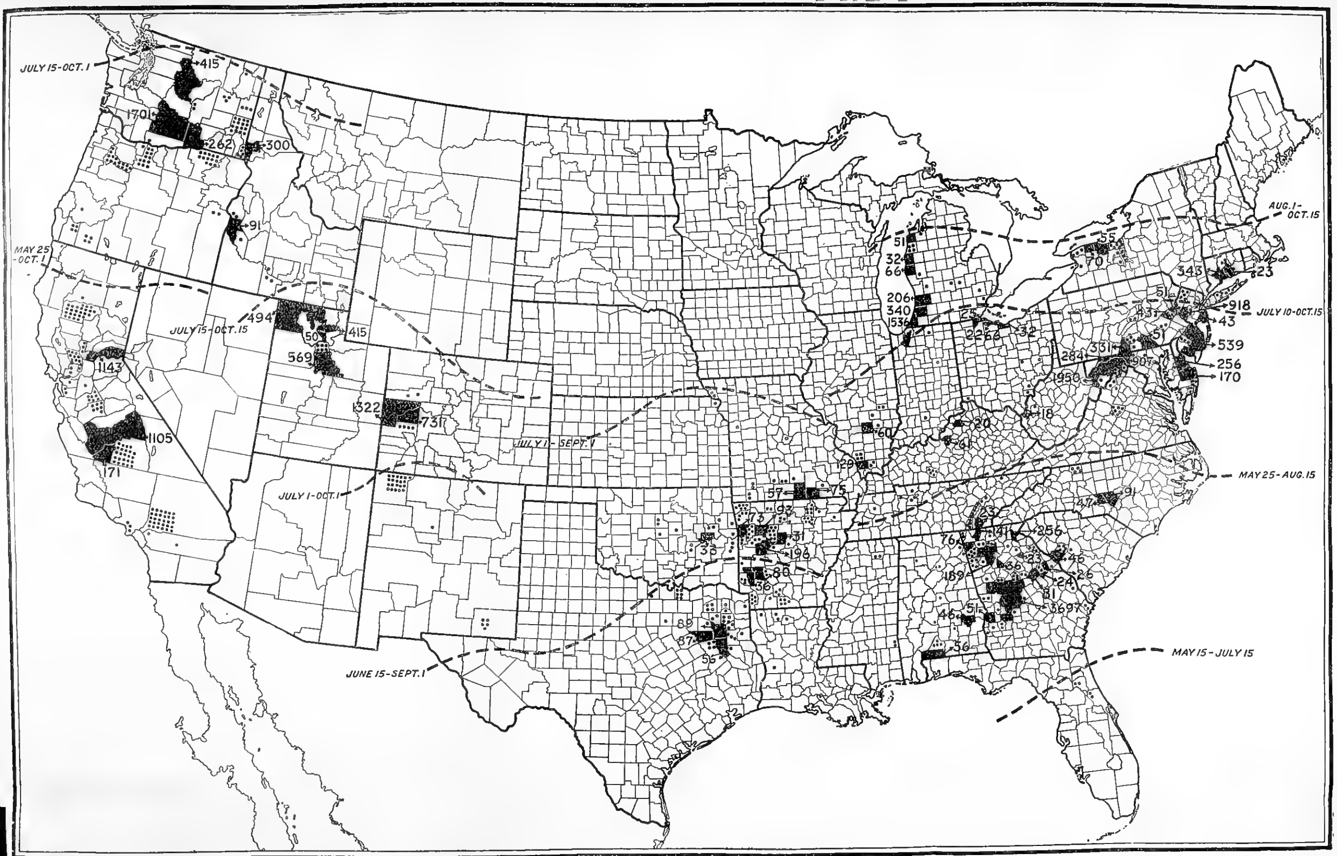

FIG. 3.—Map showing peach shipments in 1914. Each dot represents five carloads, or fraction thereof. The black areas represent the number of carloads indicated by figures.

These figures refer to the entire crop including those areas which are close to market and which do not contribute largely to the car-lot movement. They also include all fruit produced for canning and evaporating and the enormous aggregate which is produced in home orchards and for strictly local consumption.

It appears reasonable to assume that a large part of the indicated excess over the production of 1914 will appear as added commercial shipments this season. This indicates that there will be a much larger proportionate increase of shipments than of total production. The best-informed marketing organizations and distributing agencies are anticipating for the country as a whole one of the heaviest commercial peach movements in the history of the industry.

PEACH SHIPMENTS, 1914.

All numbers which are marked with an asterisk (*) are estimates, based upon the shipments for 1913, figures furnished for the 1914 crop previous to its being marketed, and estimates for the 1915 crop. Figures for the actual shipments in 1914 from these stations have not been obtained.

ALABAMA.

(June 20 to Aug. 1.)

	Carloads.
Atmore	47.0
Peachburg	46.0
Owassa	16.5
Malta	8.0
Reids	8.0
Haleyville	5.0
Thorsby	3.5
Fort Payne	2.0
Peterbaugh	2.0
Canoe	1.0
Lapine	1.0
Minter	1.0
Camp Hill	.5
Bangor	.0
State total	141.5

ARKANSAS.

(SOUTHWESTERN SECTION.)

(July 1 to Aug. 25.)

	Carloads.
Highland	75.5
Nashville	32.0
El Dorado	18.0
Knoxville	15.0
Stephens	10.0
Amity	9.0
De Queen	7.5
Junction City	6.0
Delight	4.0
Horatio	4.0
Mineral Springs	2.8
Buena Vista	2.0
Lockesburg	1.5
Chidester	1.0
Dierks	1.0
Gillham	1.0
Waldo	1.0
Stamps	.8
Grannis	.5
King	.5
Mena	.5
Blevins	.3
Smackover	.3
Brister	.0
Camden	.0
Emmett	.0
Hatfield	.0
Hope	.0
Magnolia	.0
Mineral	.0
Patmos	.0
Rosboro	.0
Wesson	.0
Van Duzer	.0
Wickes	*.0
Total	194.2

(NORTHERN SECTION.)

(July 10 to Sept. 1.)

	Carloads.
Ola	99.0
Dardanelle	72.0
Alma	56.0
Russellville	31.3
Clarksville	30.0
Coal Hill	28.0
Texarkana	25.0
Cushman	23.5
Morrillton	21.0
Williford	16.0
Leslie	15.0
Rogers	13.5
Cabin Creek	13.0
Magazine	11.3
Altus	11.0
Plumerville	10.0
Centerville	9.0
Ozark	9.0
Van Buren	9.0
Belleville	8.0
Hackett	8.0
Lincoln	8.0
Springdale	8.0
Atkins	7.5
Capps	7.0
Hardy	7.0
Hartman	7.0
Gentry	6.0
Mulberry	5.0
Newark	5.0
Imboden	4.5
Ravenden	4.5
Gravette	4.0
Havana	4.0
Waveland	4.0
Casa	3.3
Arlberg	3.0
Decatur	3.0
Black Rock	1.0
Conway	1.0
Denning	1.0
Jonesboro	1.0
Mile Post No. 130	1.0
Mountainburg	1.0
Rudy	1.0
Avoca	.5
Booneville	.5
Dyer	.5
Greenland	.5
Lancaster	.5

ARKANSAS—Continued.

	Carloads.
Lowell	.5
Oneal	.5
Tontitown	.5
Bellfonte	.3
Berryville	.3
Green Forest	.3
Mammoth Spring	.3
Prairie Grove	.3
St. Joe	.3
Abbott	.0
Barber	.0
Batavia	.0
Bentonville	.0
Bergman	.0
Blue Mountain	.0
Centerton	.0
Chapman	.0
Charleston	.0
Chester	.0
Crickett	.0
Danville	.0
Doniphan	.0
Farmington	.0
Fayetteville	.0
Felker	.0
Garfield	.0
Greenwood	.0
Harrison	.0
Highfill	.0
Hiwassee	.0
Huntington	.0
Johnson	.0
Marsnall	.0
Mile Post No. 115	.0
Plainview	.0
Schaberg	.0
Siloam Springs	.0
Smeltzer	.0
Springtown	.0
Steel	.0
Sulphur Rock	.0
Sulphur Springs	.0
West Fork	.0
Winslow	.0
Total	622.2
State total	816.4

CALIFORNIA.

(May 25 to Oct. 1.)

Newcastle	571.0
Loomis	365.0
Sanger	310.0
Kingsbury	250.0
Selma	200.0
Penryn	162.0
Cucamonga	148.0
Parlier	143.0
Armona	141.0
Corning	123.0
Fresno	68.5
Winters	55.0
Del Ray	43.0
Tulare	43.0

CALIFORNIA—Continued.

	Carloads.
Clovis	40.0
Auburn	38.0
Hanford	30.0
Dinuba	28.0
Yam	23.0
Fowler	20.0
Reedley	13.0
Sultana	12.0
Yuba City	12.0
Cutler	11.0
Riverbank	11.0
Suisun	10.3
Oleander	10.0
Denair	8.0
Pasadena	8.0
Swall	8.0
Hemet	7.0
Lincoln	7.0
Oakdale	7.0
Oakland	7.0
Anderson	5.0
Guinda	4.0
Loma	4.0
Seville	4.0
Yettem	4.0
Cornwall	3.0
Los Angeles	3.0
Visalia	3.0
Antioch	2.0
Bowles	2.0
Merced	2.0
Laton	2.0
Monmouth	2.0
Winton	2.0
Corona	1.0
Miley	1.0
Stockton	1.0
Woodsbro	1.0
State total	2,983.8

COLORADO.

(July 15 to Oct. 1.)

Palisade	1,096.0
Paonia	405.0
Clifton	211.0
Hotchkiss	152.0
Austin	78.0
Delta	73.0
Lazear	23.0
Montrose	16.0
Grand Junction	15.0
Grand Valley	5.0
Silt	1.0
Fruita	.0
State total	2,075.0

CONNECTICUT.

(Aug. 10 to Oct. 10.)

East Wallingford	225.0
Wallingford	69.0
Middlefield	23.0
Yalesville	22.0

CONNECTICUT—Continued.

	Carloads.
Tracy	14.0
Meriden	13.0
South Glastonbury	11.0
Deep River	.3
Berlin	.0
Cheshire	.0
Farmington	.0
Highwood	.0
New Britain	.0
State total	377.3

DELAWARE.

(Aug. 1 to Sept. 15.)

Wyoming	244.0
Bridgeville	67.0
Seaford	*50.0
Milford	24.0
Milton	21.0
Harrington	7.0
Lincoln	5.0
Ellendale	3.0
Houston Station	2.0
Woodside	2.0
Farmington	.5
Greenwood	.0
Smyrna	.0
State total	425.5

FLORIDA.

(May 15 to July 15.)

Seville	9.0
Edgar	3.0
McMeekin	3.0
State total	15.0

GEORGIA.

(June 15 to Aug. 1.)

Fort Valley	1,526.0
Marshallville	565.0
Byron	265.0
Lee Pope	122.0
Warm Springs	102.0
Reynolds	96.0
Adairsville	94.0
Woodbury	92.5
Trebor	84.0
Bradley	81.0
Zenith	80.0
Mount Airy	79.0
Cohutta	77.0
Gray	70.0
Mayfield	66.0
Kitchens Siding	55.0
Summerville	54.0
Betts Siding	53.0
Hartleys	53.0
Baldwin	50.0
Cornelia	50.0
Americus	48.0
Montezuma	47.0
Red Clay	40.0

GEORGIA—Continued.

	Carloads.
Slappeys Siding	40.0
James	36.0
Richland	35.0
Williamson	32.0
Wilsons Mill	32.0
Elberta	26.0
Thomson	26.0
Hillsboro	25.0
Agricola	24.0
Cleveland	23.0
Roberta	23.0
Lorane	20.5
Dyas	20.0
Keithsburg	20.0
Varnell	20.0
Alto	19.0
Middleton	19.0
Musella	19.0
Thomaston	19.0
Goggins	17.0
Grovania	17.0
Round Oak	17.0
Univeter	17.0
Barnesville	16.0
Emerson	15.0
Linden	15.0
Lizella	15.0
Oakhurst	15.0
Crest	14.0
Renfroes	13.0
Wayside	13.0
Jasper	11.0
Marietta	11.0
Silver Creek	11.0
Perry	10.5
Culverton	10.0
Rome	10.0
Yatesville	9.0
Halls	8.0
Millers	8.0
Rockmart	8.0
Shiloh	8.0
Butler	7.0
Hopedale	7.0
Trenton	7.0
Dawson	6.0
Menlo	6.0
Norwood	6.0
Zebulon	6.0
Bremen	5.0
Calhoun	5.0
Dallas	5.0
Elko	5.0
Rover	5.0
Smyrna	5.0
Sparta	5.0
Stevens Siding	5.0
The Rock	5.0
Berzelia	4.0
Dalton	4.0
Eatonton	4.0
Hunters Siding	4.0
Putnam	4.0
Stone Mountain	4.0

GEORGIA—Continued.

	Carloads.
Wellston	4.0
West Lake	4.0
Newnan	3.5
Cuthbert	3.3
Allston Spur	3.0
Ball Ground	3.0
Chambers	3.0
Commerce	3.0
Gainesville	3.0
Hollywood	3.0
Persico	3.0
Bolingbroke	2.0
Culloden	2.0
Dennis	2.0
Greenville	2.0
Harrisburg	*2.0
Molena	2.0
Plainville	2.0
Reeves	2.0
Rising Fawn	2.0
Willard	2.0
Ellijay	1.5
Orchard Hill	1.5
Lyerly	1.3
Arlington Vineyard	1.0
Austell	1.0
Elkin	1.0
Forsyth	1.0
Fort Gaines	1.0
Klondyke	1.0
Macon	1.0
Nona	1.0
Shannon	1.0
Sofkee	1.0
Cave Springs	.5
Dooling	.5
Meda	.5
Tifton	.5
Walden	.5
Douglasville	.3
Mitchell	.3
Beall Springs	.0
Canton	.0
Griffin	.0
State total	4,803.7

IDAHO.

(Aug. 15 to Oct. 1.)

	Carloads.
Lewiston	300.0
Emmett	77.0
Payette	13.5
Crystal	5.0
Buhl	3.3
Twin Falls	3.0
Filer	2.0
Boise	1.0
Gooding	1.0
Weiser	1.0
Wendell	1.0
New Meadows	.0
State total	407.8

ILLINOIS.

(Aug. 1 to Sept. 20.)

	Carloads.
Cobden	107.0
Alto Pass	*30.0
Anna	22.0
Alma	21.0
Walnut Hill	17.0
Makanda	16.0
Kinmundy	13.0
Kell	9.0
Neoga	8.5
New Burnside	8.0
Altamont	4.0
Flora	3.5
Norris City	.8
Texico	.5
Salem	.0
State total	260.3

INDIANA.

(July 20 to Sept. 1.)

	Carloads.
Mitchell	2.0
New Albany	2.0
Marion	1.0
New Paris	1.0
Claypool	.0
State total	6.0

KANSAS.

(Aug. 1 to Sept. 1.)

	Carloads.
Troy	2.0
Baldwin	.3
State total	2.3

KENTUCKY.

(July 20 to Sept. 15.)

	Carloads.
Brooks	26.0
Shepherdsville	26.0
Bowling Green	21.5
Sulphur	20.0
Stites	9.0
Cecelia	.0
State total	102.5

LOUISIANA.

(June 20 to Aug. 15.)

	Carloads.
Haynesville	5.0
Dubach	4.0
Pickering	3.3
Athens	2.5
Plain Dealing	2.0
Gibsland	.8
Dodson	.0
Minden	.0
Ruston	.0
State total	17.6

MARYLAND.

(WESTERN SECTION.)

(Aug. 1 to Oct. 10.)

	Carloads.
Smithsburg	699.0
Potomac	156.8
Rawlings	111.0
Edgemont	86.0
Shockeys	43.0
Chewsville	21.5
Rohrersville	18.0
Hancock	14.0
Spring Gap	13.0
Cavetown	12.0
Cohill	9.0
Cumberland	3.5
Asbestos	3.0
Hagerstown	2.0
Woodmont	2.0
Deerfield	1.0
Mapleville	.0
Total	1,194.8

(BAY SECTION.)

(Aug. 1 to Sept. 15.)

Pocomoke City	30.0
Preston	3.0
Worton	3.0
New Windsor	.3
Berlin	.0
Goldsboro	.0
Henderson	.0
Total	36.3
State total	1,231.1

MICHIGAN.

(Aug. 1 to Oct. 15.)

	Carloads.
Benton Harbor	1,132.0
Coloma	334.0
Fennville	191.0
Hartford	116.0
South Haven	77.0
Kibbie	70.0
Shelby	40.0
Bangor	37.0
Lacota	37.0
Frankfort	35.0
Watervliet	32.0
Ludington	27.0
Beulah	16.0
New Era	10.0
Sodus	10.0
Allegan	9.5
Hart	8.0
New Buffalo	8.0
Mears	7.0
Riverside	6.0
Onekama	5.5
Arcadia	5.0
Grand Junction	5.0
Manistee	5.0

MICHIGAN—Continued.

	Carloads.
Fountain	4.0
St. Joseph	4.0
Union Pier	4.0
Bravo	3.0
Sawyer	3.0
Grant	2.0
Grand Rapids	2.0
Owosso	2.0
St. Johns	2.0
Bloomingdale	1.5
Traverse City	1.5
Wayland	1.3
Birmingham	1.0
Breedsville	1.0
Bridgman	1.0
Clarkston Station	1.0
Detroit	1.0
Durand	1.0
Eau Claire	1.0
Fremont	1.0
Lee	1.0
Pontiac	1.0
Rothbury	1.0
Royal Oak	1.0
Scottsville	.5
Stevensville	.5
Bailey	.3
Custer	.3
Almont	.0
Brunswick	*.0
Casnovia	.0
Free Soil	.0
Harbert	*.0
Howell	.0
Kent City	.0
Montague	.0
Newark	.0
Newaygo	.0
Paw Paw	.0
Sparta	.0
Whitehall	.0
State total	2,266.9

MISSISSIPPI.

(June 20 to July 15.)

Ingomar	9.0
State Line	8.0
Vosburg	.5
State total	17.5

MISSOURI.

(Aug. 1 to Sept. 1.)

Koshkonong	45.0
Brandsville	27.0
Haskins Spur	16.0
Elberta	15.0
Torrey	10.0
Olden	8.5
Marionville	6.0
Forest City	5.0
Saint Elmo	5.0

MISSOURI—Continued.

	Carloads.
Cassville	4.0
Mountain Grove	3.5
Pomona	3.0
Cedar Gap	2.0
Oregon	2.0
Exeter	1.8
Seligman	1.8
Willow Springs	1.5
Blue Springs	1.3
Cabool	1.0
Forbes	1.0
Hunter	1.0
Jefferson City	1.0
Logan	1.0
Monett	1.0
Seymour	1.0
Washburn	1.0
Diggins	.5
Fordland	.5
Hutton Valley	.5
Norwood	.5
Richmond	.5
Rockport	.5
Bois D' Arc	.3
Burnham	.3
Doniphan	.3
Lanagan	.3
Mansfield	.3
Thayer	.3
Ash Grove	.0
Aurora	.0
Branson	.0
Hollister	.0
Independence	.0
Lebanon	.0
McCracken	.0
Morley	.0
Mountain View	.0
Purdy	.0
Rushville	.0
West Plains	.0
State total	171.2

NEW JERSEY.

(July 20 to Sept. 15).

Lebanon	409.0
White House Station	284.0
Elm	275.0
Ammandale	126.0
Hammonton	106.0
Flemington	57.0
Moorestown	44.0
Middletown	41.0
Landisville	38.0
Califon	33.0
Mount Holly	29.0
Glenwood	25.0
Vineland	24.0
Glassboro	15.5
Main Avenue	14.0
Somerville	10.0
High Bridge	6.3
Wheat Road	6.0

NEW JERSEY—Continued.

	Carloads.
Phillipsburg	4.0
Plainfield	3.0
Red Bank	2.0
Bloomsbury	1.0
Greenwich	1.0
Hampton	1.0
Masonville	1.0
Egg Harbor City	.8
Jutland	.3
Sussex	.0
State total	1,556.9

NEW MEXICO.

(July 1 to Oct. 1.)

Farmington	83.5
Carlsbad	*25.0
Aztec	12.0
Cedar Hill	3.0
Bernalillo	2.5
Flora Vista	2.0
Hendrix	2.0
State total	130.0

NEW YORK.

(Aug. 20 to Oct. 10.)

Calverton	31.0
Morton	29.5
Williamson	23.0
Carlton	15.5
Lyndonville	15.5
Barker	13.0
Holley	13.0
Caywood	11.0
Rochester	10.0
Kendall	8.0
Hamlin	6.0
Buffalo	5.5
Ashwood	5.0
Penn Yan	5.0
Albion	3.0
Hilton	3.0
Sodus	3.0
Walker	3.0
Brockport	2.5
Medina	2.5
Brice	2.0
Fancher	2.0
Geneva	2.0
Millers	1.5
Knowlesville	1.0
Lewiston	1.0
Lockport	1.0
Eagle Harbor	.8
Warwick	.8
Charlotte	.5
Fruitland	.3
Ontario	.3
Adams Basin	.0
Appleton	.0
Barnard	.0
Burt	.0

NEW YORK—Continued.

	Carloads.
East Williamson	.0
Elberta	.0
Florida	*.0
Gasport	.0
Greece	.0
Highland	*.0
Himrods	.0
Junius Station	.0
Kendaia	.0
Lodi	.0
Marlboro	*.0
Milton	.0
Model City	.0
Newfane	.0
New Milford	.0
North Rose	.0
Ransomville	*.0
Ripley	.0
Spencerport	.0
Union Hill	.0
Walcott	.0
Walworth	.0
Waterport	.0
Wilson	.0
Youngstown	.0
State total	221.2

NORTH CAROLINA.

(June 1 to Aug. 15.)

Aberdeen	60.0
Candor	47.0
Southern Pines	22.0
Mount Airy	18.0
Eagle Springs	8.0
Carthage	1.0
Mount Tabor	.0
State total	156.0

OHIO.

(Aug. 1 to Oct. 10.)

Gypsum	857.0
Danbury	488.0
Oak Harbor	341.0
Port Clinton	250.0
Lakeside	114.0
Catawba Island	112.0
Lacarne	101.0
Waterville	25.0
Sandusky	15.0
Berlin Heights	10.0
Vermilion	7.0
Guysville	5.5
Cincinnati	5.0
Frazeysburg	3.0
Middle Bass	3.0
Middleport	2.0
Quaker City	2.0
Madison	.0
Painesville	.0
State total	2,340.5

OKLAHOMA.

(July 1 to Sept. 1.)

	Carloads.
Checotah	33.0
Crescent	7.0
Poteau	7.0
Wetumka	7.0
Oklahoma	5.0
Muskogee	4.3
Boynton	4.0
Hulbert	4.0
Cameron	2.0
Spiro	2.0
Muldrow	1.0
Sparks	1.0
Stilwell	1.0
Haskell	.8
Sallisaw	.5
Jones	.3
Marble City	.3
Wynnewood	.3
Ardmore	.0
Bestin	.0
Cement	.0
Chickasha	.0
Chocktaw	.0
Coyle	.0
Crowder	.0
Elgin	.0
Fitzhugh	.0
Fletcher	.0
Fort Towson	.0
Guthrie	.0
Harrah	.0
Lawton	.0
McLoud	.0
Manitou	.0
Meridian	.0
Mulhall	.0
Mustang	.0
Oakwood	.0
Panama	.0
Park Hill	.0
Perry	.0
Rush Springs	.0
Russet	.0
Spencer	.0
Tahlequah	.0
Teague	.0
Witcher	.0
Yale	.0
State total	80.5

OREGON.

(July 15 to Sept. 15.)

The Dalles	[1] 60.0
Freewater	39.0
Salem	39.0
Waconda	22.0
Milton	21.0
Brooks	13.0
Ashland	12.0
Merlin	12.0
Brogan	7.0

[1] An equivalent of 25 cars, included here, was picked up by boats at landings along the Columbia River within 40 miles of The Dalles

OREGON—Continued.

	Carloads.
Grants Pass	4.5
Medford	4.0
Hermiston	3.0
Hood River	3.0
Dillard	1.0
Talent	1.0
Brownsville	.5
Central Point	.5
Chemawa	.5
Phoenix	.5
Rogue River	.5
Mosier	.3
State total	244.3

PENNSYLVANIA.

(Aug. 15 to Oct. 15.)

Midvale	151.0
Dillsburg	51.0
Easton	50.0
Quincy	45.0
Scotland	40.5
Ledy	* 40 0
Walberts	36.0
Waynesboro	31.3
Mont Alto	* 12.0
Lehmasters	11.0
Shippensburg	11.0
Boyertown	10.0
Middleburg	7.0
Allentown	6.5
Mechanicsburg	5.3
Orwigsburg	4.5
Bethlehem	1.0
McKnightstown	1.0
Orrtanna	1.0
Beavertown	0.5
Beaver Springs	.0
Chambersburg	.0
Fayetteville	.0
Trout Run	.0
State total	515.6

SOUTH CAROLINA.

(May 25 to Aug. 10.)

Clarks Hill	24.0
Meriwether	20.0
Ridge Spring	17.0
Monetta	4.0
Batesburg	2.0
Modoc	2.0
Leesville	1.0
Johnston	.0
State total	70.0

TENNESSEE.

(July 15 to Aug. 15.)

Sale Creek	25.5
Cleveland	23.0

TENNESSEE—Continued.

	Carloads.
Dayton	13.0
Harriman	9.5
Van Leer	6.0
Spring City	4.5
Trenton	3.5
Tennessee Ridge	3.0
Cumberland Gap	2.0
Lone Oak	1.0
Bakewell	.0
Greer	.0
State total	91.0

TEXAS.

(June 15 to Aug. 15.)

Athens	56.0
Winona	33.0
Alto	26.0
Collinsville	24.0
Tyler	22.0
Frankston	18.0
Arp	16.0
Lindale	15.0
Sulphur Springs	14.0
Peachland	12.0
Jacksonville	11.5
Murchison	11.0
Morrill	9.0
Longview	8.8
Ash	7.0
Mount Selman	6.0
Winsboro	6.0
Baxter	5.0
Telmah	5.0
Brownsboro	4.0
Grand Saline	4.0
Henderson	4.0
Larue	4.0
Ogburn	4.0
Whitesboro	4.0
Pickton	3.0
Gilmer	2.5
Maydelle	2.5
Beckville	2.0
Pittsburg	2.0
Tatum	2.0
Como	1.5
Mount Pleasant	1.3
Swan	1.3
Atlanta	1.0
Big Sandy	1.0
Bullard	1.0
Cookville	1.0
Flint	1.0
Fort Worth	1.0
Fruitland	1.0
Overton	1.0
Pritchett	1.0
Rhonesboro	1.0
Sacul	1.0
Craft	.8
Grapeland	.8

TEXAS—Continued.

	Carloads.
Winfield	.8
Appleby	.5
Carthage	.5
Denison	.5
Merrimac	.5
Chico	.3
Omaha	.3
Sunset	.3
Woodlawn	.3
Ballinger	.0
Barstow	.0
Bowie	.0
Brunswick	.0
Chandler	.0
Chatterton	.0
Clarendon	.0
Clyde	.0
Crockett	.0
Emory	.0
Gladewater	.0
Lassater	.0
Latexo	.0
Marshall	.0
Mineola	.0
Mount Vernon	.0
Nacogdoches	.0
Naples	.0
Neches	.0
New Baden	.0
Pine	.0
Pottsboro	.0
Queen City	.0
Rusk	.0
Scottsville	.0
Timpson	.0
State total	364.0

UTAH.

(Sept. 1 to Oct. 15.)

Ogden	341.0
Brigham	337.0
Provo	322.0
Springville	139.5
Willard	103.0
Roy	72.3
Pleasant Grove	69.0
Clearfield	40.0
Payson	38.8
Salt Lake City	27.0
Corrine	25.0
Dewey	14.0
Woods Cross	9.0
Tremonton	8.0
Honeyville	7.0
Uinta	2.0
Collington	1.0
Farmington	.3
State total	1,555.9

VIRGINIA.

(Albemarle Section.)

(July 15 to Oct. 1.)

	Carloads.
Crozet	17.0
Greenwood	11.0
Afton	1.5
Total	29.5

(Lower Shenandoah Valley Section.)

(July 15 to Oct. 1.)

	Carloads.
Stephenson	11.0
Winchester	11.0
Fishers Hill	5.0
Rileyville	5.0
Edinburg	4.0
Maurertown	1.0
Woodstock	.5
Clear Brook	.3
Lenore	.0
Strasburg	.0
Strasburg Junction	.0
Toms Brook	.0
Total	37.8
State total	67.3

WASHINGTON.

(July 15 to Oct. 1.)

	Carloads.
Parker	583.0
Wenatchee	400.0
Donald	365.0
North Yakima	253.0
Zillah	226.0
Kennewick	166.3
Wapato	150.0
Buena	61.0
Bishop	41.5
Hanford	33.0
Grand View	26.0
Riparia	25.0
White Bluffs	24.0
Silcott	22.0
Prosser	21.5
Cashmere	15.0
Creston	* 15.0
Spokane	13.0
Hover	10.0
Wawawai	9.5
Flint	9.0
Trinidad	6.5
Sunnyside	6.3
Vernita	4.5
White Salmon	4.0
Meyers Falls	3.0
Kiona	2.0
Mabton	2.0
Sawyer	2.0
Emerald	1.0
Farmington	1.0
Benton City	.3
Underwood	.3
Auburn	.0
Gibbon	.0
Lynden	.0
Sumas	.0
Touchet	.0
Walla Walla	*.0
State total	2,501.7

WEST VIRGINIA.

(July 10 to Oct. 15.)

	Carloads.
Romney	617.0
Keyser	411.0
Vanderlip	203.5
Springfield	177.0
Patterson's Creek	174.0
French	82.0
Sleepy Creek	71.0
Cherry Run	49.5
Ridgedale	32.3
Globe	30.6
Petersburg	18.0
Huntington	17.5
Tabler	15.0
Paw Paw	14.0
Martinsburg	13.0
Pinto	12.0
Ridgeway	7.0
McNeill	6.0
Okonoko	6.0
Buffalo	5.0
Moorefield	4.0
Little Cacapon	3.8
Wapacoma	3.2
Durgon	3.0
Summit Point	2.5
Belleville	.0
Coxs Landing	.0
Green Spring	.0
North Mountain	.0
State total	1,977.9
Grand total	27,994.2

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

A System of Accounting for Cooperative Fruit Associations. By G. A. Nahstoll and W. H. Kerr. Pp. 25. 1915. (Department Bulletin 225.)

Strawberry Supply and Distribution in 1914. By Wells A. Sherman, Houston F. Walker, and O. W. Schleussner. Pp. 10. 1914. (Department Bulletin 237.)

Outlets and Methods of Sale for Shippers of Fruits and Vegetables. By. J. W. Fisher, jr., J. H. Collins, and Wells A. Sherman. Pp. 27. 1915. (Department Bulletin 266.)

Methods of Wholesale Distribution of Fruits and Vegetables on Large Markets. By J. H. Collins, J. H. Fisher, jr., and Wells A. Sherman. Pp. 28, figs. 2. 1915. (Department Bulletin 267.)

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Canning Peaches on the Farm. By H. P. Gould and W. F. Fletcher. Pp. 26, figs. 14. (Farmers' Bulletin 426.)

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Growing Peaches: Varieties and Classification. By H. P. Gould. Pp. 13. (Farmers' Bulletin 633.)

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The Cold Storage of Small Fruits. By S. H. Fulton. Pp. 28, pls. 3. 1907. (Bureau of Plant Industry Bulletin 108.) Price 15 cents.

The Control of Peach Brown-rot and Scab. By W. M. Scott and T. Willard Ayers. Pp. 26, figs. 1, pls. 4. 1910. (Bureau of Plant Industry Bulletin 174.) Price 10 cents.

Peach Growing for Market. By Erwin F. Smith. Pp. 24, figs. 21. 1895. (Farmers' Bulletin 33.) Price 5 cents.

Experiment Station Work with Peaches. By C. B. Smith. Pp. 399–434, figs. 13. 1906. (Office of Experiment Stations Document 1029.) Price 5 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 299

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER. December 13, 1915

THE ASHES: THEIR CHARACTERISTICS AND MANAGEMENT.

By W. D. Sterrett, *Forest Examiner*.

CONTENTS.

IMPORTANCE OF ASH FOR FOREST MANAGEMENT.

The ash genus (*Fraxinus*), containing 18 or more native species, is of considerable importance for forest management in the United States. Because of its fine qualities, which make it valuable in the handle, butter-tub, vehicle, boat-oar, athletic goods, and other industries, and because the supply is limited and the annual output small, ash timber of good grade commands a high price. The tree lends itself readily to both natural and artificial reproduction, has a good rate of growth under proper conditions, responds well to thinnings made to increase its growth, and is comparatively free from destructive attacks of insects and diseases. It is probably more desirable than the other common heavy hardwoods—oak, hickory, maple, birch, and beech—for commercial timber growing on sites to which it is adapted, as it is merchantable when smaller and is usually higher priced and faster growing. It will be one of the first woods the demand for which will exceed the supply. Handle producers as a class feel that they will soon be facing a serious shortage of ash timber, and have as yet been unable to find anything to take its place satisfactorily.

This bulletin aims to make clear the economic status of ash; to differentiate the species, in regard to which there is considerable confusion, and to indicate their relative importance; to describe the characteristics of the more important species; and to outline methods of forest management for commercial growing of ash timber.

THE LUMBER CUT OF COMMERCIAL SPECIES.

The census returns for the past decade indicate an annual cut of from 200 to 300 million feet of ash lumber, less than 1 per cent of the total cut of all species and between $2\frac{1}{2}$ and 3 per cent of the total cut of hardwoods. In rank in lumber production ash stands twentieth or twenty-first among all species and tenth or eleventh among hardwoods. In addition to the lumber cut the census returns show 25 to 35 million board feet of ash used annually in slack cooperage for staves, heading, and hoops. The total annual cut in lumber and cooperage appears to be about the same as for hickory or for cottonwood. Ash does not figure in the census returns for poles, ties, and other products.

The census figures indicate further that the annual production of ash lumber was maintained or somewhat increased during the decade from 1899 to 1909, but since that time it has considerably decreased. In average f. o. b. value per 1,000 board feet of ash lumber there was an increase of 54 per cent in 1909 over 1899. This increase in price was not maintained during succeeding years, however, which is due largely to an increased proportion of lower grades in the total output. A general survey of the supply of ash timber leads to the conclusion that the high-water mark in the production of ash lumber in the United States, both in quantity and quality of output, has been passed, and it is not likely that either the amount or value of the 1909 cut will ever be equaled.

Another interesting point to be observed in the census figures is the constant shifting in rank of ash-lumber-producing States. In 1899 the cut in Michigan, which was from virgin forests, was greater than in any three other States combined, while in 1911 Michigan had dropped to seventh place, with an output one-sixth as great as that of 1899. Ohio and Indiana, where the cut is practically all from second growth, ranked third and fifth, respectively, in 1909, but rose to first and third places in 1911, although in each case there was considerable decrease in the actual amount of the output. Arkansas, on the other hand, where the cut is from old-growth forest, dropped from first to second place in 1911 and decreased 40 per cent in amount of production from 1909 to 1911. If the production of ash for cooperage stock were added to the lumber cut, however, Arkansas would still be far in the lead. These figures indicate the waning importance of old as compared with second growth. The decline in total production is due to the impossibility of the second growth's keeping pace with the annual cut, which will be increasingly marked as the supply of old growth disappears.

About 98 per cent of the ash lumber produced in the United States is from the three important commercial species—white (*F. americana*), green (*F. lançeolata*), and black ash (*F. nigra*). The species which make up the remaining 2 per cent of the lumber cut are Oregon (*F. oregona*), blue (*F. quadrangulata*), Biltmore (*F. biltmoreana*), pumpkin (*F. profunda*), and red ash (*F. pennsylvanica*), which all have good silvicultural possibilities. Commercially there are only two kinds of ash lumber recognized—white ash and brown ash—and even these are usually sold together under the common name of ash, because many of the uses to which the lumber is put do not require their separation. The term "green ash" is unknown commercially, and all the lumber cut from this species is marketed as white ash or simply ash.

Tables 1 and 2 show for each species its cut in each ash-producing region of the United States, its proportion of the total cut, and its relative importance in the region. These tables are based on census data for 1910. From these data the cut of ash by counties was determined and careful estimates made by the author of the proportion of each species in each county for which a report was made by the census.

TABLE 1.—*Cut of ash, by regions and species.*

Region.	Per cent of total in United States.	Total cut in region (1,000 board feet).	White ash.[1]		Green ash.[2]		Black ash.	
			1,000 board feet.	Per cent of total in region.	1,000 board feet.	Per cent of total in region.	1,000 board feet.	Per cent of total in region.
New England	5.5	12,965	10,865	83.8	....	....	2,100	16.2
Middle Atlantic States	7.4	17,370	13,945	80.3	55	0.3	3,370	19.4
Lake States (Michigan, Wisconsin, Minnesota)	19.3	45,334	13,630	30.1	1,606	3.5	30,098	66.4
Ohio, Indiana, Illinois, West Virginia, Kentucky, Tennessee	32.8	76,927	53,950	70.1	16,437	21.4	6,540	8.5
South Atlantic States and Alabama	5.7	13,307	5,405	40.6	7,902	59.4	....	....
Lower Mississippi Valley, including Missouri, Arkansas, Oklahoma, Texas, Louisiana, and Mississippi	28.8	67,678	6,900	10.2	60,778	89.8	....	....
Kansas, Nebraska, Iowa, and South Dakota	.2	534	185	34.6	349	65.4	....	....
Washington, Oregon, California[3]	.3	600	....	....	....	....	....	....
Total	100	234,715	104,880	44.7	87,177	37.1	42,108	17.9

[1] Includes small per cent of Biltmore and blue ash.
[2] Includes small per cent of pumpkin and red ash.
[3] All Oregon ash.

TABLE 2.—*Distribution by regions of the cut ash of the different species, expressed in per cent of the total cut of each species.*

Region.	White ash.	Green ash.	Black ash.
	Per cent.	*Per cent.*	*Per cent.*
New England	10.4		5
Middle Atlantic States	13.3	0.1	8
Lake States (Michigan, Wisconsin, Minnesota)	13	1.8	71.5
Ohio, Indiana, Illinois, West Virginia, Kentucky, Tennessee	51.4	18.9	15.5
South Atlantic States and Alabama	5.1	9.1	
Lower Mississippi Valley, including Missouri, Arkansas, Oklahoma, Texas, Louisiana, and Mississippi	6.6	69.7	
Kansas, Nebraska, Iowa, and South Dakota	.2	.4	
	100	100	100

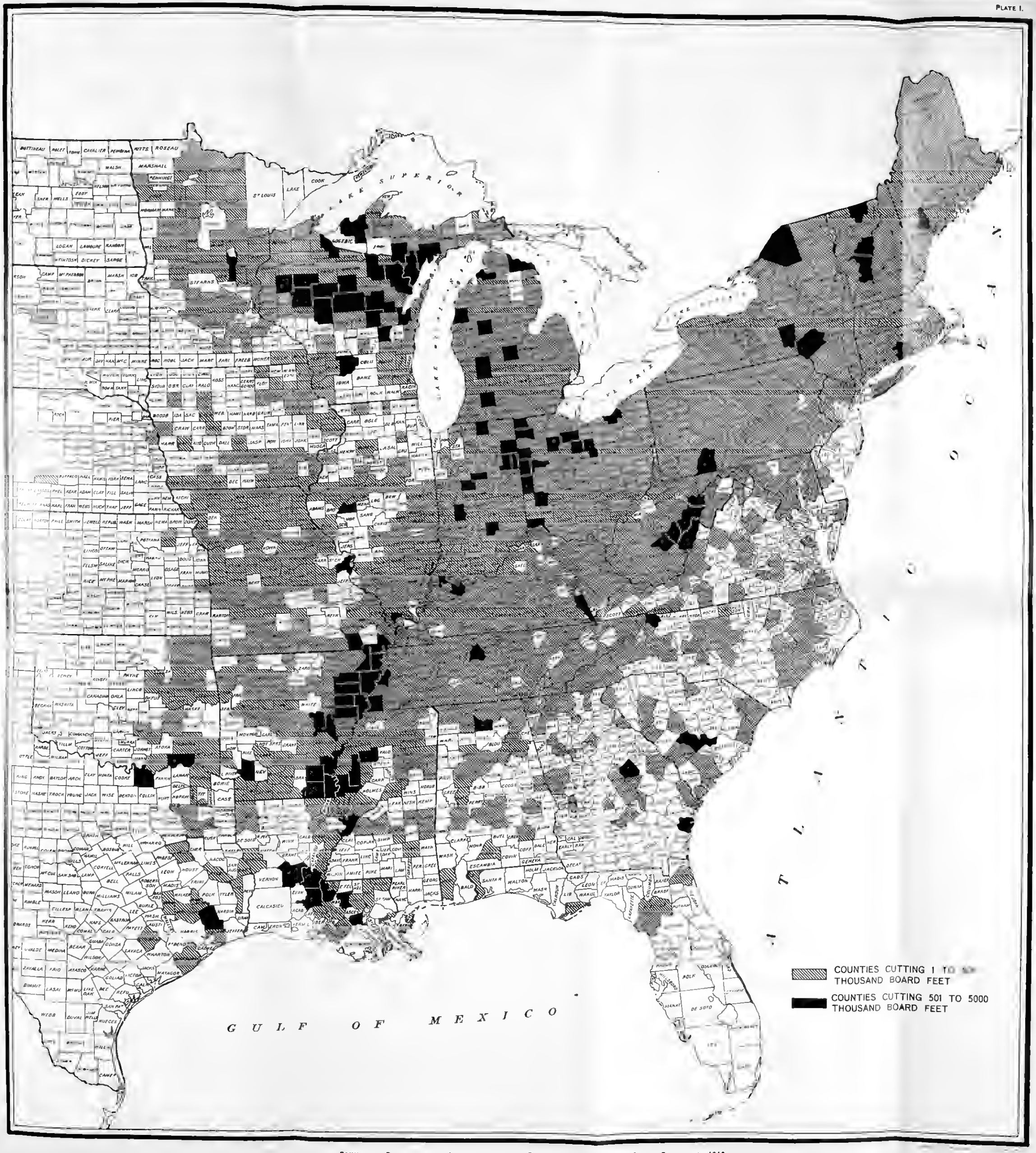
In round numbers, white ash comprises 45 per cent, green ash 37 per cent, and black ash 18 per cent of the total output of ash lumber in the United States. The percentage of Oregon ash is insignificant. If the cut of ash for slack cooperage were included, green ash would be just ahead of white ash. These tables show white ash to be the important species in New England, the Middle Atlantic, and the Central States; green ash in the South Atlantic States, the lower Mississippi Valley, and in Iowa, Kansas, Nebraska, and South Dakota; and black ash in the Lake States—Michigan, Wisconsin, and Minnesota. Over half the total supply of white ash comes from the Central States; 70 per cent of the green ash comes from the lower Mississippi Valley, and 71.5 per cent of the black ash from the Lake States. Over 60 per cent of the total supply of ash comes from the Central and lower Mississippi Valley States, 19 per cent from the Lake States, 13 per cent from New England and Middle Atlantic States, and only 5.7 per cent from the South Atlantic States.

The areas of heaviest lumber production of ash in the United States are indicated by Plate I (map showing the cut of ash by counties for the year 1910.)

CONSUMPTION OF ASH BY WOOD-USING INDUSTRIES AND ITS VALUE FOR DIFFERENT USES.

Practically all of the ash lumber reported by the United States Census is consumed in different wood-using industries. The high value and scarcity of the wood precludes its use in general construction work. Investigations by the Forest Service indicate that a larger amount of ash was used in the wood-manufacturing industries than the census figures report as being manufactured into lumber and cooperage stock. This is probably due to the manufacture of handles, butter tubs, and vehicle stock directly from logs and bolts. In round numbers, 22 per cent of the ash used in industries goes into handles; 20 per cent into butter-tub staves and headings; 15 per

F LUMBER CUT BY COUNTIES IN



COMMERCIAL DISTRIBUTION OF ASH AS INDICATED BY CENSUS RETURNS OF LUMBER CUT BY COUNTIES IN 1910 cent into vehicles, including automobiles; 7 per cent into planing-mill products; 6 per cent each into furniture, refrigerators and kitchen cabinets, and car construction; 3 per cent each into boxes and crates, agricultural implements, and ships and boats (chiefly oars), and 1 per cent each into fixtures, sporting and athletic goods, musical instruments, machine construction, and hames. It is also used in small quantities for pump sucker rods, tanks, pulleys and conveyers, trunks, printing materials, rollers, elevators, picker sticks, professional and scientific instruments, brushes, patterns and flasks (for foundry work), litters, and airship frames and propellers.

Long handles for shovels, forks, hoes, and rakes of all kinds, short "D" handles for shovels and spades, and boat-hook handles are made almost entirely from ash, as it alone seems to have the proper combination of qualities—straightness of grain, a high degree of stiffness and strength perpendicular to the grain, suitable weight and hardness, and capacity to wear smooth in use. The same qualities make it desirable for agricultural implements, sporting and athletic goods, and boat oars. For making handles, rapid-growing second-growth white and green ash, which yield the strongest and stiffest wood, are the best and the most often used. Old-growth ash is usually considered too fine grained and brittle for handles. All standard baseball bats are made from ash of the strongest second growth. Practically all long oars and sculls (14 feet and over in length) and a large percentage of short oars and paddles are made from ash. For large-sized oars select old growth is much used in order to get the proper size. Black ash as a rule is not suitable for oars, as it will water-soak and become soft and spongy.

About 90 per cent of creamery butter tubs are made from ash, for which it is the most desirable wood because it imparts no disagreeable flavor. For the same reason it is extensively used in refrigerators, kitchen cabinets, and churns. Its wood is very easily worked up into staves and heading for tubs and churns, the supply coming mostly from bottomland green ash of the lower Mississippi Valley. Ash hoops are made mostly from black ash in the Lake States.

In the vehicle and automobile industries strong second-growth white and green ash is used extensively as bentwood for bows, as a substitute for hickory and white oak for tongues, and for single and double trees. Ash is also used for vehicle bodies and panels, for which old growth of all species is preferred, as it can be obtained in greater widths, is not so liable to warp as second growth, and holds glue better.

For planing-mill products, furniture, and car construction old-growth ash is usually preferred because a high degree of strength and stiffness is not required or because large sizes or widths are necessary. Black ash (called brown ash commercially) makes especially handsome interior finish.

Second-growth ash of good quality will usually bring the best price as handle, boat-oar, vehicle, or agricultural-implement stock rather than as lumber. This excludes ash grown in swamps, which is too fine-grained and soft.

Old-growth ash of fair size and quality brings the best price if cut into lumber and graded, the upper grades being sold for car construction, vehicle and automobile bodies and panels, and planing-mill products, the lower grades for furniture, refrigerators, and possibly the cull stuff for butter-tub heading. In exceptional cases high-grade old-growth ash timber can best be sold for boat oars.

Ash timber of poor quality for lumber can probably best be sold for stave and heading bolts for butter tubs or used for firewood or charcoal. It is also used in some parts of the country for fence posts and bars where more suitable kinds of trees are lacking.

Ash timber of old or second growth, suitably located, can often be sold most advantageously for export logs. Five to seven million feet of green ash logs are exported annually in addition to the several million feet of ash exported in the form of deals and planks.

GROUPS AND SPECIES OF AMERICAN ASH.

The ashes in the United States may be divided into five groups, containing in all 18 or more species, distinguished from each other as shown in the key (Table 3).

TABLE 3.—*Key to American ashes.*

Genus FRAXINUS.—Trees and shrubs with opposite, pinnately compound leaves, and fruit a dry samara. Divisible into five groups: *white*, *green*, *water*, *black*, and *shrub* groups, distinguished on the basis of flowers and fruit.

- I. Flowers without petals, diœcious, polygamous, or perfect.
  - A. Body of fruit terete or nearly so. Wings not extending to base of seed. Bark fissured. Flowers diœcious.
    - 1. WHITE ASH GROUP.. Wings of samara terminal or nearly so.
      - *a.* Twigs glabrous.
        - (1) *F. americana*—seed with wing, 1 to 2 inches long.
        - (2) *F. texensis*—seed with wing, less than inch long. Hardly more than a form of *F. americana*.
      - *b.* Twigs and lower surface of leaflets pubescent.
        - (3) *F. biltmoreana*.

2. Green Ash Group. Wings of samara decurrent on body of seed to its middle.
   - *a.* Twigs, petioles, and pedicels glabrous.
     - (4) *F. lanceolata*[1]—leaflets 7 to 9 in number, 3 to 6 inches in length, lanceolate to acuminate, and rachis grooved.
     - (5) *F. berlandieriana*—leaflets 5 to 7 in number, 2 to 6 inches in length, oval or obovate.
   - *b.* Twigs, petioles, and pedicels velvety pubescent.
     1. Leaflets stalked, subsessile, or sessile—eastern species.
        - (6) *F. profunda*—samara 2½ to 3 inches long, samara body somewhat compressed, leaflets stalked.
        - (7) *F. pennsylvanica*[1]—samara 1 to 2 inches long, samara body round and long-linear, leaflets sometimes sessile.
     2. Leaflets subsessile or sessile—western species.
        - (8) *F. oregona*—seed body slightly compressed (Pacific coast tree).
        - (9) *F. velutina*[2]—seed body round (southwestern tree).
        - (10) *F. coriacea*—seed body compressed. Thicker, more leathery, longer-stemmed, and broader leaflets than *F. velutina.*

B. Fruit body compressed. Seed kernel long-linear and terete as in green ash. Wings of samara extending to its base and broad. Bark light gray with small, thin, closely appressed scales. Flowers diœcious.

3. Water Ash Group.
   - (11) *F. caroliniana*—leaflets 5 to 7, ovate-oblong; fruit elliptical to spatulate, often 3-winged, acute at apex.
   - (12) *F. pauciflora*—leaflets 3 to 5, oblong; fruit lanceolate to oblanceolate, rounded and emarginate at apex. Hardly more than a form of *F. caroliniana.*

C. Fruit body and seed kernel flat. Wings of samara extending to its base, and broad. Bark gray and scaly. Flowers perfect or polygamous.

4. Black Ash Group.
   - *a.* Twigs 4-sided; flowers perfect.
     - (13) *F. quadrangulata*—5 to 9 leaflets, ovate-oblong to lanceolate, coarsely serrate, rounded or wedge-shaped at base.
     - (14) *F. anomala*—1 to 3 leaflets (mostly 1); flowers sometimes polygamous.
   - *b.* Twigs round; flowers polygamous; northern species.
     - (15) *F. nigra*—leaflets 5 to 11, oblong-lanceolate, gradually acuminate, laterals being sessile.

---

[1] Dr. Britton in his Illustrated Flora (1913 ed.) gives *F. lanceolata* as a pseudonym for *F. pennsylvanica* and gives two other species in this group distinguished from *F. pennsylvanica* as follows:

Wing of samara long-linear .... *F. darlingtonii.*
Wing of samara long-linear spatulate or oblong-spatulate:
Samaras broadly spatulate; leaves firm, entire .... *F. michauxii.*
Samaras narrowly spatulate; leaves thin, serrate, or entire .... *F. pennsylvanica.*

In addition he has *F. campestris*, with lateral leaflets sessile, as a western plains form of *F. pennsylvanica.*

[2] Under this is included *F. toumeyi* (Britton), with leaflets distinctly stalked, a rare form.

II. Flowers with petals, polygamous or perfect—shrubs or small trees of the southwest.

5. SHRUB ASH GROUP.

(16) *F. cuspidata*—panicles terminal on lateral leafy branches of the year; 3 to 7 leaflets, lanceolate and ovate-lanceolate.

(17) *F. greggii*—panicles axillary on branches of the year or previous year; 3 to 7 leaflets, narrowly spatulate to oblong-ovate; petioles wing-margined.

(18) *F. dipetala*—twigs of season's growth 4-angled and smooth; 5 to 9 leaflets, smooth and thick.

The three important commercial species of ash—white, green,[1] and black—occur in different groups, named accordingly. The other two groups, water and shrub ash, contain species of little or no importance for forest purposes. The botanical range of the different species of American ash is shown in Plate II.[2]

The separation into groups is based on differences in flowers and fruits, and further separation into species is chiefly on differences in twigs, leaves, and fruits. Of less importance in identification are bark characteristics and general appearance.

Plate III shows the differences in the seed of different groups, also some of the variations of different species in the same group. The white ash group has the wing of the seed terminal and seed body round and plump. The green ash group has the wing extending along the body of the seed to about its middle, and the seed body round, but slim and long. The water and black ash groups both have the wings extending all around the seed body, the first having a round, slim, long seed kernel, and the second a flattened, broad seed kernel.

Plates IV to VII show differences in leaves and twigs, as well as seed, of the important species of ash. It is important to observe that the last year's growth on red, Biltmore, pumpkin, and water ashes is pubescent, while that on green, white, and Texan ashes is glabrous.

White and green ash group species have a decidedly fissured bark (Pl. VIII, fig. 1, and Pl. XI, fig. 2) when a foot or more in diameter, while black, blue, and water ash have a scaly bark (Pl. IX). Green ash has finer twigs than white ash, and in the open grows more bushy. Biltmore ash has stouter looking twigs than white ash, and red ash stouter ones than green ash.

In practical identification of ash trees, wherever there is any doubt as to the species, it is well to decide first to which group a tree belongs. The geographic range (see map, Pl. II), habitat, and associated species should be considered. For instance, a swamp ash tree in the Atlantic

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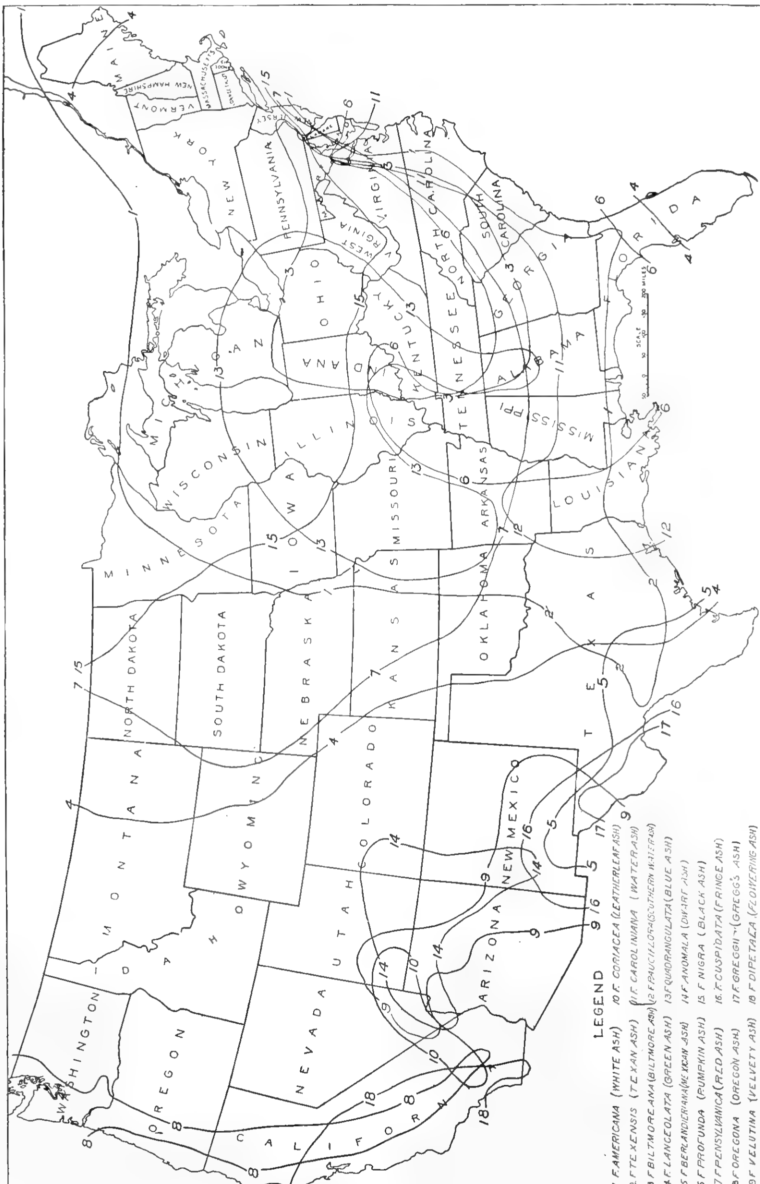
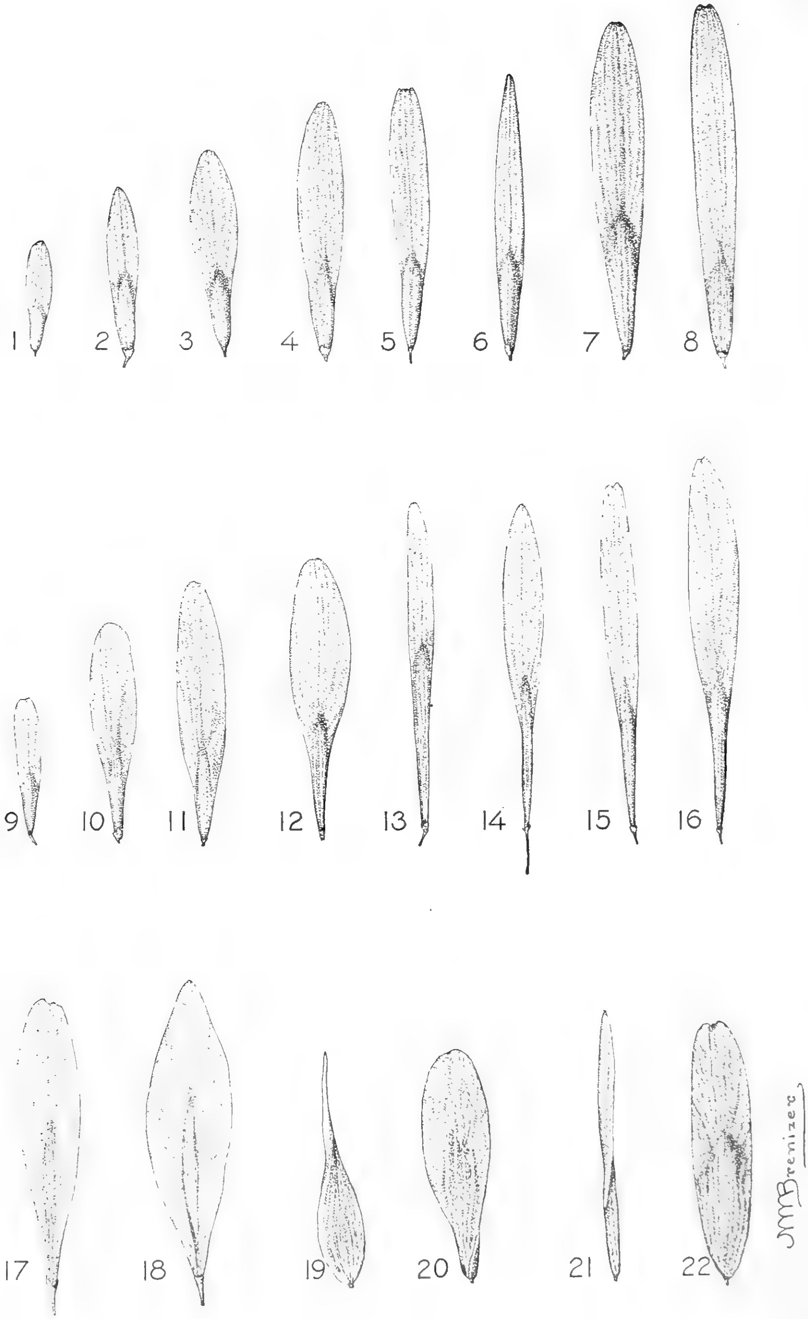
[1] Green ash (*F. lanceolata*) is regarded by many as a variety of red ash (*F. pennsylvanica*) on account of the fact that the two forms run together, especially west of the Mississippi. Botanical nomenclature would indicate that the pubescent *F. pennsylvanica* is the important species because named first, but from an economic standpoint it is of very secondary importance to the glabrous form, *F. lanceolata*. In the white ash group the glabrous form, *F. americana*, is economically the important one, but in this case it is also botanically established as the important species.

[2] Prepared by W. H. Lamb of the Forest Service and the author.



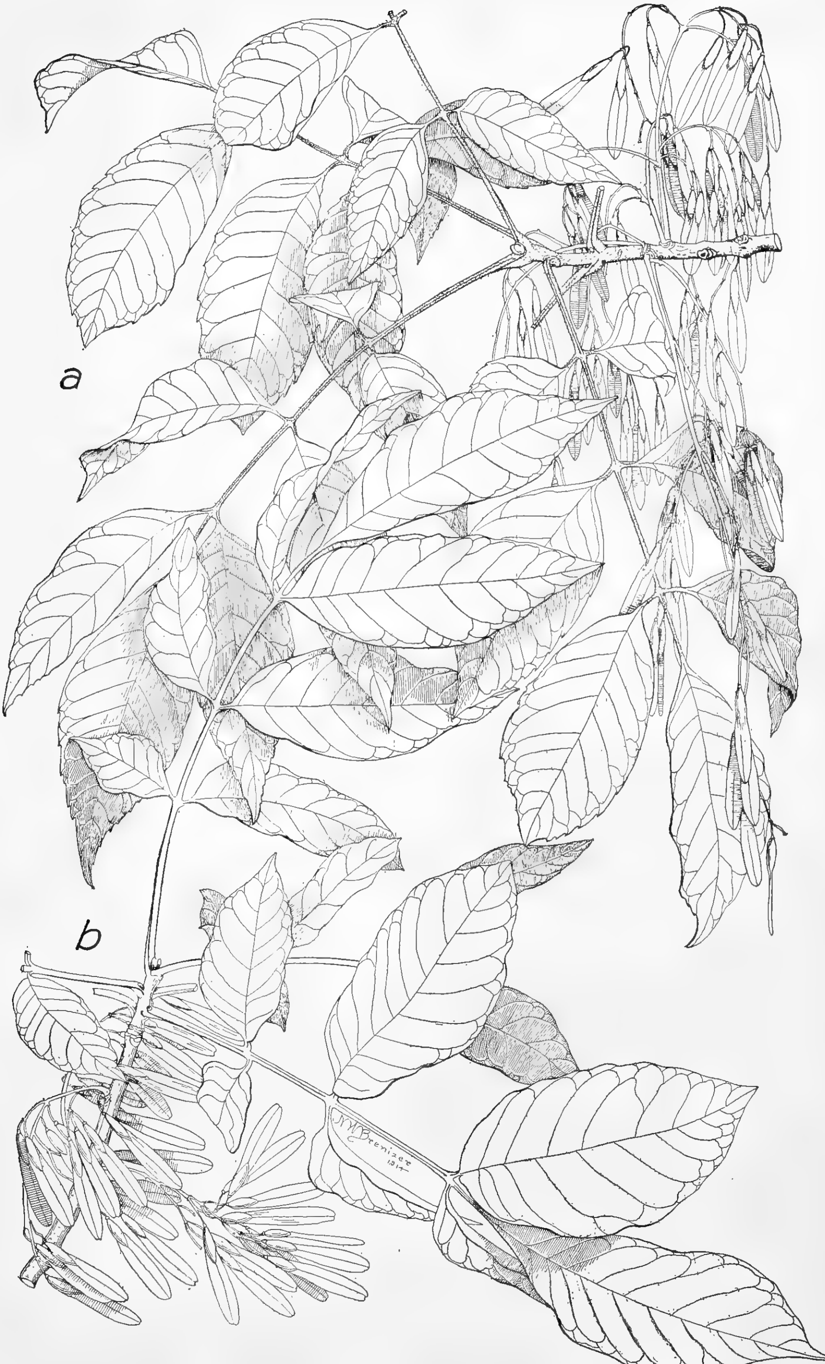
BOTANICAL RANGE OF AMERICAN ASHES.

The index numbers are the same as used in Tables 3 and 4.

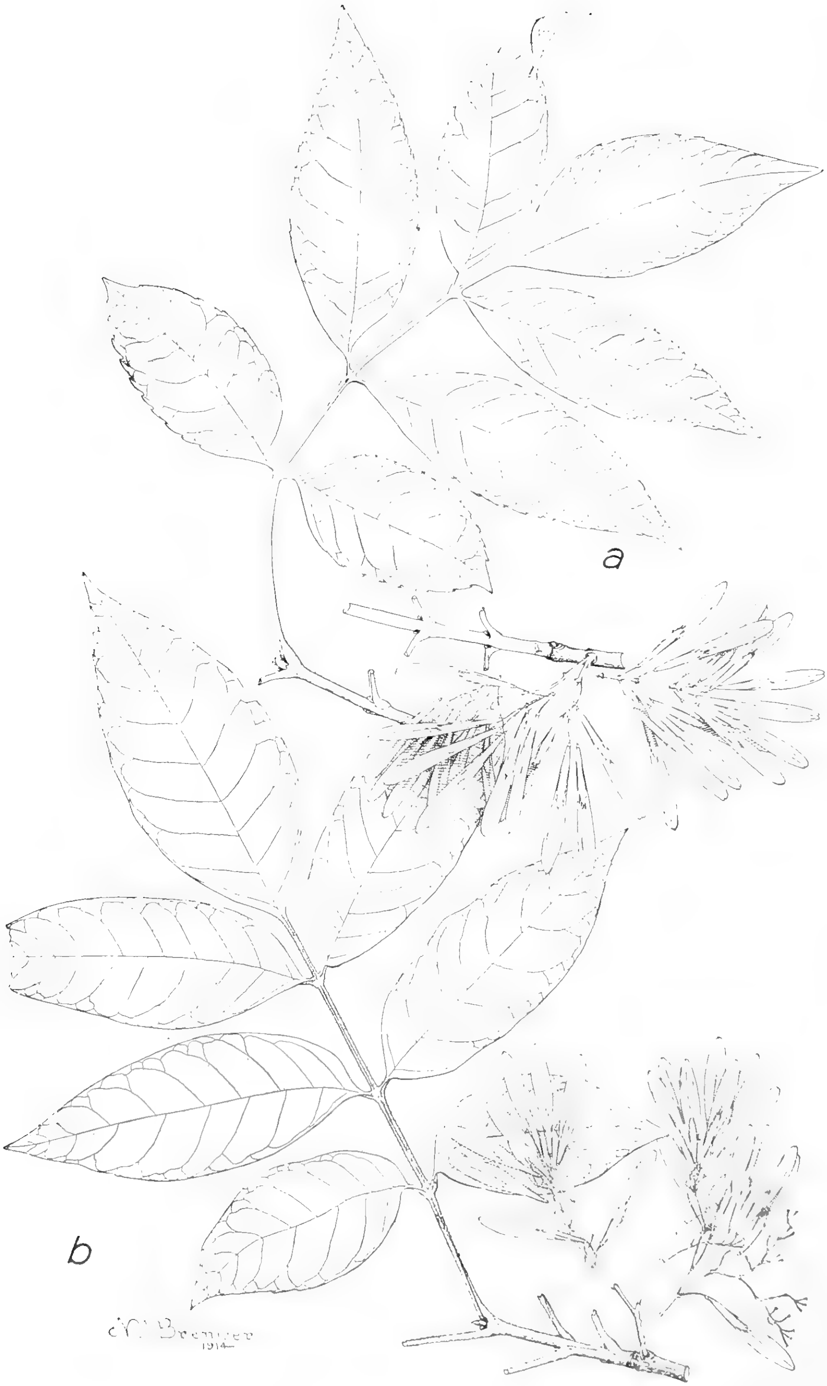


ASH SEED, NATURAL SIZE.

Nos. 1-8, seed of the white ash group: No. 1, *F. texensis;* Nos. 2, 4, and 8, *F. biltmoreana;* Nos. 3, 5, 6, and 7, *F. americana.* Nos. 9-16, seed of the green ash group: No. 12, Britton's *Michauxii;* No. 13, Britton's *F. darlingtonii;* the remainder show variations in size and shape of seed of *F. lanceolata* and *F. pennsylvanica.* Nos. 17-18, seed of the water ash group: No. 17, *F. pauciflora;* No. 18, *F. caroliniana.* Nos. 19-22, seed of the black ash group: Nos. 19-20, profile and face view of a *F. quadrangulata* seed, showing characteristic twist; Nos. 21-22, profile and face view of a *F. nigra* seed, which is characteristically flatter than *F. quadrangulata.*

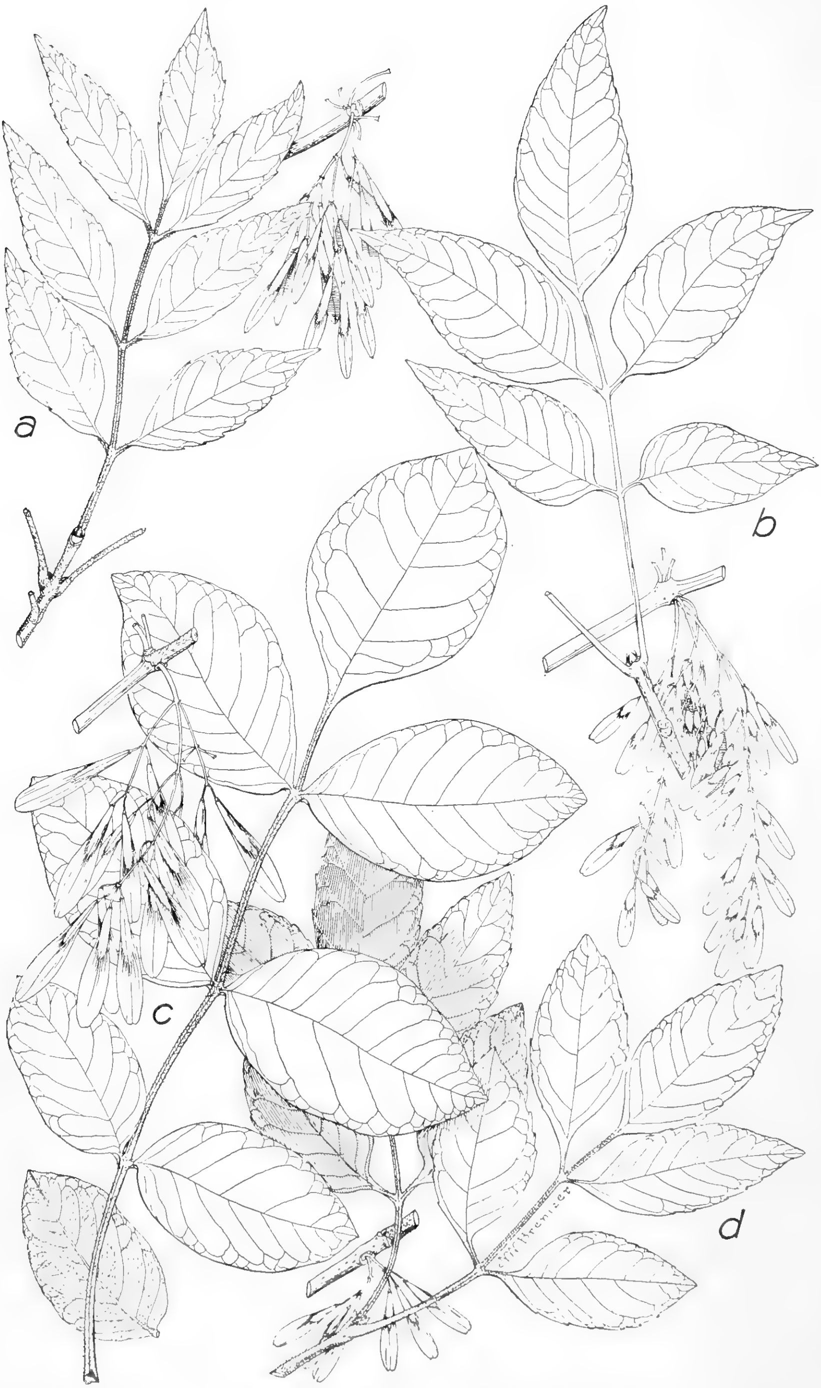


LEAVES AND SEED OF (*a*) F. BILTMOREANA, (*b*) F. AMERICANA.



LEAVES AND SEED OF (*a*) F. LANCEOLATA, (*b*) F. PENNSYLVANICA.

LEAVES AND SEED OF (*a*) F. CAROLINIANA, (*b*) F. NIGRA, (*c*) F. QUADRANGULATA, (*d*) F. PROFUNDA.



LEAVES AND SEED OF (a) F. VELUTINA, (b) F. TEXENSIS, (c) F. OREGONA, (d) F. CORIACEA.

Coastal Plain would likely be *F. caroliniana*, a tree in Oregon or Washington would be *F. oregona*, etc. Where all the necessary botanical characteristics are present identification is easy, but the most important one, seed, is usually absent. This is especially the case with the two most important ashes, white (*F. americana*) and green (*F. lanceolata*), and the groups they represent, both of which, however, are readily distinguished from the black ash group. Where seed is absent it is especially important to consider geographic distribution, site occurrence, and associated species in distinguishing white and green ash. But where both species are found on the same site, as occasionally happens, identification by means of differences in leaves and twigs, bark, and general appearance is the best that can be done. White ash has more robust twigs and buds than green ash, bark usually darker colored, and leaves a darker green color, green ash leaves being more yellowish.

SILVICULTURAL SIGNIFICANCE OF THE GROUPS AND THEIR DISTRIBUTION.

The division into botanical groups also has silvicultural significance. The white ash group is primarily of upland ashes; the green ash group is primarily of bottom-land ashes growing on sites with fair natural drainage during part of the year; the water ash group is of swamp trees; trees of the black ash group occur usually on unfavorable sites, the black ash in cold northern swamps, and the blue ash on dry limestone hills; the shrub group is of chaparral species of the southwest, where climatic conditions are especially severe.

The extent of range and character of distribution of the several groups is influenced to a great degree by reproductive factors, as these determine largely a tree's relative aggressiveness. They include lightness of seed (ease of dissemination), quickness of germination and seedling development, durability of the seed, and frequency of seed years. Climatic, soil, moisture, and light requirements and susceptibility to injury also have considerable influence. All these things vary a great deal in the five groups as a result of the process of adaptation to a wide range of conditions. The green ash group is the most aggressive and widely distributed; the white ash next; and water and black ash groups the least aggressive and the least able to hold their own.

The green ash group has the widest geographical distribution because it seeds most frequently, and has the lightest seed, with the quickest germination—quick to take hold of a favorable opening. (Pumpkin ash is an exception, as it has the heaviest seed of any ash, is not prolific, and has a limited distribution.) The natural local habitat of the green ash group is chiefly moist to wet bottom lands or the banks of watercourses. The seed is not durable and must find immediately favorable conditions for germination, especially moisture. This group has naturally a better chance of holding its own or even of increasing, like paper birch, through the interference of man, than any of the groups. Since this group has become the most widely distributed, it is natural that it should have produced more species than other groups in adapting itself to varied climatic conditions. The species vary, from those with smooth twigs and leaves, common where climatic or soil conditions are favorable, to very pubescent forms where severe conditions prevail. (See botanical range map, Plate II.)

The white ash group also has a wide geographic range, but less than green ash, because it seeds much less freely; the seeds are as a rule heavier and larger and less easily disseminated, and take much longer to germinate. On the other hand, their seed is more durable, larger kerneled, and stouter, and adapted to somewhat more rugged conditions, so that it has a better chance of germinating and growing than green ash where soil conditions happen to be adverse to immediate growth. Trees of this group occur chiefly on uplands, especially in coves, on moist slopes and depressions, and along upland watercourses.

None of the species in the water or black ash groups have as wide a geographic range as does green or white (see Pl. II), because their seed is heavier and less readily disseminated, and in the case of the black ash group seeding is less frequent. Black ash (*F. nigra*) is the wider distributed of the two and extends farther north than white ash, but not nearly so far south. Certain characteristics of trees of these groups, such as durability of seed of the black ash group and the wide flat wing of the water ash seed which by floating it increases its chance of finding a favorable spot for germination, enable them to perpetuate themselves on unfavorable sites to which they have been relegated by their nonaggressive character. The species of these groups, except blue ash (*F. quadrangulata*), occur chiefly in swamps where conditions are poor for tree reproduction and growth. Blue ash is primarily a tree of rough and dry limestone hills, where conditions for reproduction are also somewhat severe and where acorn and other nut trees are the prevailing growth. These nonaggressive groups are likely to decrease continually in amount and importance.

The shrub group is confined to a very limited area in the Southwest, and may be classified as secondary chaparral species, though not considered desirable even for this kind of forest.[1]

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[1] See Forest Service Bulletin No. 85, "Chaparral," by F. G. Plummer.

RELATIVE IMPORTANCE OF THE DIFFERENT SPECIES.

The relative importance for commercial or silvicultural purposes of the different species of American ash is shown in Table 4.

TABLE 4.—*Relative importance of the different species of ash.*

WHITE ASH GROUP.	
1. White ash (*F. americana*)	Commercially and silviculturally the most important American ash. Commercially important east of the Mississippi, except in the Atlantic and Gulf Coastal Plain region. A tree primarily of fertile, moist, upland soils and of coves, and of stream banks where drainage is good.
2. Texan ash (*F. texensis*)	A variety of white ash of no commercial importance, but of some silvicultural possibilities. Occurs on dry limestone bluffs and ridges in northern, central, and western Texas, from Dallas to the Devils River.
3. Biltmore ash (*F. biltmoreana*)	A variety of white ash of some slight commercial importance and with good silvicultural possibilities. Adapted to somewhat drier sites and makes more rapid growth in youth. Chief occurrence in Tennessee, Kentucky, Ohio, and Indiana, especially on limestone formations, at lower elevations than white ash.
GREEN ASH GROUP.	
4. Green ash (*F. lanceolata*)	Commercially and silviculturally nearly equal to white ash in importance. Commercial occurrence limited chiefly to the river bottoms subject to overflow of the Atlantic and Gulf Coastal Plains. Has extended up the Mississippi and its tributaries into Colorado, Wyoming, Montana, Manitoba, and Saskatchewan. The most widely distributed of the ashes.
5. Mexican ash (*F. berlandieriana*).	No commercial importance. Chief occurrence in Mexico. Used for street and plaza planting with good success in cities of the Mexican tableland, but of no importance for the United States.
6. Pumpkin ash (*F. profunda*)	Of some slight commercial importance in river bottoms in southeastern Missouri and eastern and central North Carolina. Found in sloughs with cypress, where it is soft and of very slow growth. On well-drained land more rapid-growing than green ash, especially in youth, and has good silvicultural possibilities. Seed scarce.
7. Red ash (*F. pennsylvanica*)	Of slight commercial importance because too infrequent, but adapted to somewhat drier sites than green ash. West of the Mississippi often not distinguished from green ash.

8. Oregon ash (*F. oregona*)......Of some slight commercial importance in the coast region of the Northwest, on river flats. Occurs from sea level to 3,000 feet elevation, but of merchantable size, usually below 2,000 feet. Occurs in river bottoms and along streams with alder, laurel, maple, walnut, cottonwood, willow, oak, and in the lower limits of Douglas fir forest. It has excellent silvicultural possibilities.

9. Velvety ash (*F. velutina*)....Very slight commercial importance. Good possibilities as a shade and windbreak tree in the arid Southwest, especially if irrigated. Range vicinity limited to the Southwest, along streams.

10. Leatherleaf ash (*F. coriacea*)..No commercial importance. Closely related to *F. velutina*, occurring in the same region, and is adapted to even more severe climatic conditions and suitable for similar uses.

WATER ASH GROUP.

11. Water ash (*F. caroliniana*)...Of very slight commercial or silvicultural importance. Deep river swamps of Atlantic and Gulf Coastal Plains from Virginia to Texas. Trees small and scattering, chiefly under shade of larger trees.

12. Water ash (*F. pauciflora*).....Of very slight commercial or silvicultural importance. Less frequent than *F. caroliniana*. Deep swamps in St. Marys River, Ga., to lower Appalachicola River, Fla. (Sargent).

BLACK ASH GROUP.

13. Blue ash (*F. quadrangulata*)..Commercially of some slight importance, chiefly in the limestone regions of Kentucky, Tennessee, Indiana, and Ohio. Better wood than black ash, and good for planting on dry limestone soils. Not a good reproducer.

14. Single leaf ash (*F. anonola*)..No commercial or silvicultural importance—not much more than a shrub. Grows along streams in arid country—McElmo River, southwestern Colorado, through Utah, to southern Nevada.

15. Black ash (*F. nigra*).........Commercially the third most important ash, but wood inferior to white and green ash. In plantations it grows equally fast. It is primarily a tree of northern swamps, not a good reproducer, and not holding its own in second-growth forests.

SHRUB ASH GROUP.

No commercial or silvicultural importance.

16. *F. cuspidata*.................Rocky slopes and dry ridges, valley of Rio Grande, in Texas and New Mexico, southward into Mexico.

17. *F. greggii*...................Dry limestone cliffs and ledges, valley of Rio Grande, from mouth of San Pedro to that of Pecos River, south into Mexico.

18. *F. dipetala*....................Near foothill streams and in gulches; in dryish or slightly moist rocky and gravelly soils; in clumps mingled with other chaparral species; inner coast ranges and foothills of the Sierra Nevada in California.

OCCURRENCE OF IMPORTANT SPECIES AND THEIR ASSOCIATES.

Ash, with its wide geographic distribution and many different forms and species, naturally occurs on a great variety of sites and in many forest types, but usually forms only a small percentage of the trees of any stand. Exceptions to this are the occurrence of green ash as a principal tree on limited areas of overflow river bottoms of the Mississippi and its tributaries, but usually in comparatively young stands less than 100 years old; of white ash as a principal tree (very rarely) on small areas of second-growth upland hardwood stands on fairly moist soil; and of black ash as occasionally a principal tree in virgin swamp forests of the Lake States. In old-growth virgin stands white and green ash never form more than a small percentage of the merchantable stand, which is mainly of longer-lived, more persistent trees, such as the oaks, birch, beech, sugar maple, yellow poplar, hemlock, white pine, and spruce, red gum, and cypress. Any agency removing the old growth, such as lumbering, often gives white and green ash a chance to become, by their good natural reproduction, relatively more important in the second growth.

WHITE ASH.

White ash occurs on comparatively well-drained sites along small streams, in swales and coves, and on moist north and east slopes, usually where the soil is both moist and permeable. It will grow even in comparatively wet places, provided there is good underdrainage. It occurs in three distinct forest types or associations of trees, in all of which hardwoods predominate: (1) birch-beech-maple-basswood type; (2) mixed oaks and chestnut type; (3) yellow poplar type. In places these types often merge into each other. White ash occurs most frequently in the birch-beech-maple-basswood and the yellow poplar types, where it attains good development and is usually a dominant forest tree. In the mixed oaks and chestnut type it is usually subordinate.

The birch-beech-maple-basswood type is the common northern hardwood forest, which extends south into the Appalachian Mountains at constantly higher elevations to northern Georgia and Alabama. The hardwoods of this type include yellow and black birch, beech, hard and soft maples, basswood, white ash, white elm, bitternut hickory, and black cherry; and in the southern Appalachians, cucumber, yellow buckeye, chestnut, and oaks. Coniferous species in the type are spruce, hemlock, and white pine, the first two especially on moist situations suitable to white ash. In original forests of this type white ash rarely forms more than from 1 to 5 per cent of the merchantable stand, but in second-growth stands it may form 20 per cent or more.

Sites on which the mixed oak and chestnut type of forest is usually found (exposed upper slopes and ridges and southern slopes) have a comparatively dry, hard soil often thin and very rocky. Such sites are not favorable to white ash, which is fastidious in regard to soil, does not readily develop a rugged, deep-going root system, as do oaks and chestnut, and requires in consequence more surface moisture. On this type white ash usually occurs as a subordinate, overtopped tree of small diameter in comparison with the oaks and chestnut, except for occasional well-developed individuals in depressions where soil and moisture conditions are more favorable. It never forms over 5 per cent of the stand. Ash reproduction takes place readily wherever the cover is slightly broken and at the same time dense enough to preserve good moisture conditions in the humus and soil; but subsequent seedling development is usually poor because conditions are adverse. The mixed oaks and chestnut type is common below 1,000 feet elevation in the glaciated hills of southern New England, southern New York, Pennsylvania, and New Jersey; farther south it occurs at increasing elevations, in the southern Appalachians up to 4,000 feet, mostly on comparatively dry southern slopes and ridges. It is common in southern Michigan, Ohio, Indiana, southern Illinois, Kentucky, and Tennessee, and in the highlands of southern Missouri and northwestern Arkansas. The most frequent associates of white ash on this type are chestnut, red, white, scarlet, black, and chestnut oaks, bitternut and pignut hickories, yellow poplar, red maple, and dogwood; other species sometimes occurring with it are swamp, white, pin, Spanish, black jack, and post oaks, black gum, black walnut, shagbark hickory, ironwood, hornbeam, elm, black cherry, shad bush, sugar maple, sassafras, hemlock, white, pitch, and shortleaf pines, scrub pine, black and yellow birch, paper birch, butternut, black locust, mulberry, beech, and red gum.

The yellow poplar type occurs only on comparatively moist, fertile sites with good drainage, such as in the hollows of small streams, north slopes, and small hollows, coves and swales interspersing drier oak or pine types. In old growth ash forms up to 10 per cent of the stand, and in second growth up to 50 per cent. The yellow poplar type is common from southern New England and southern New York (below 1,000 feet elevation) to northern Florida and west to northern Louisiana and eastern Arkansas and Missouri. Southward it is found at increasing elevations until in the southern Appalachians it reaches 3,500 feet; but it occurs also on moist, well-drained fertile sites in the Coastal and Gulf Plain region down to elevations of less than 100 feet above sea level. The chief associates of white ash on this type include yellow poplar, red, white, black, pin, and chestnut oaks, black and red gum, pignut and shagbark hickory, black walnut, and chestnut. White ash is very much outgrown by yellow poplar, and often occurs as an overtopped tree in old stands, though in this type it reaches its largest size.

BILTMORE ASH.

The pubescent form of white ash, known as Biltmore ash, is occasionally found in the mixed oaks and chestnut type and in the yellow poplar type of the southern Appalachians and Central States east of the Mississippi River. It is adapted to somewhat drier soil conditions than white ash, and has a more vigorous growth at the outset. In central Tennessee this species sometimes forms from 1 to 5 per cent of the merchantable stand of the original forest.

TEXAN WHITE ASH.

Texan white ash is adapted to dry hills of central Texas, where it occurs with post oak in noncommercial stands.

GREEN ASH.

Green ash is primarily a species of southern overflow river bottoms, most abundant in those of the Mississippi River and its tributaries south of Illinois, also common in other rivers of the Atlantic and Gulf Coastal Plains from Virginia to Texas. It has spread itself extensively along watercourses all over the upper Mississippi Valley north into Manitoba and Saskatchewan and west into Colorado and Montana. In the western and northern limits of its occurrence its place is sometimes taken by red ash, which is better able to survive on upland sites. The bottom land on which it grows is comparatively free from water during most of the growing season at least (Pl. X); it does not flourish like tupelo and cypress on land which is saturated during most of that period, although poor, suppressed specimens of great age are sometimes found on such areas. The characteristic associates of green ash on drier portions of bottom lands, often not subject to overflow, are sweet gum, cottonwood, cow and white oaks, sycamore, white elm, and persimmon; and in the inferior species are hackberry, red and silver maples, boxelder, slippery elm, Kentucky coffeetree, sassafras, dogwood, honey locust, and pawpaw. On intermediate bottom lands, often overflowed but dry during most of the growing season, green ash is characteristically associated with sweet and black gum, cow oak, willow oak, swamp white oak, pecan, hickory, red oak, hackberry, red maple, white elm, cork elm, slippery elm, river birch, willow, mulberry, persimmon, cottonwood, cypress, and tupelo gum; also (of lesser importance) honey locust, soap berry, dogwood, with a dense undergrowth (in wetter situations) of elbow brush (*Cratægus*), poison ivy, wild grapevine, and wire grasses. Green, pumpkin, and water ashes are often found around the edges of sloughs or back swamps (upon which water stands for from 9 to 12 months in a year) in mixture with cypress and tupelo gum. Green ash is one of the most common species in the very sparsely forested plains and prairie country of the Middle West, growing almost entirely along streams in company with white elm, cottonwood, willow, hackberry, sycamore, black cherry, and bur oak.

RED ASH.

Red ash is a pubescent species of the green ash group occasionally found along streams in the New England, Middle, Lake, and Central States east of the Mississippi River. West of the Mississippi it is often difficult to distinguish from green ash, with which it is apparently connected by intermediate forms.

PUMPKIN ASH.

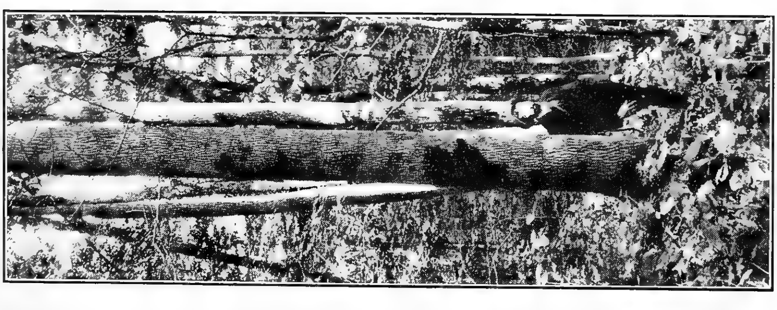
Pumpkin ash is a much more distinct pubescent species of the green-ash group than is red ash, the seeds are much larger, and the tree is more rapid growing in youth under the same conditions. It has a very limited occurrence, however, and is usually found on the wetter parts of overflow river bottoms, unfavorable to rapid development, where it is associated with the same trees as is green ash. It has been observed in commercial quantities only in southeastern Missouri, northeastern Arkansas, and in the eastern half of North Carolina. It may be, geologically, an older species than green ash, but nonaggressive from a reproductive standpoint and relegated to undesirable sites.

OREGON ASH.

Oregon ash occurs along streams, in some cases reaching an elevation of 5,000 feet, though it usually stops at 3,000. It thrives on gravelly flats with the water table near the surface. At low elevations it is associated with maple, oak, and willow. At higher elevations in the oak-digger-pine type and in the Douglas-fir-yellow-pine type, its associates are willow, alder, maple, cottonwood, black oak, yellow and digger pine, and Douglas fir. The largest trees and the commercially important stands are in southwestern Oregon, in association with alder, broadleaf maple, and California laurel, on good agricultural soils which are being rapidly cleared for farm land.

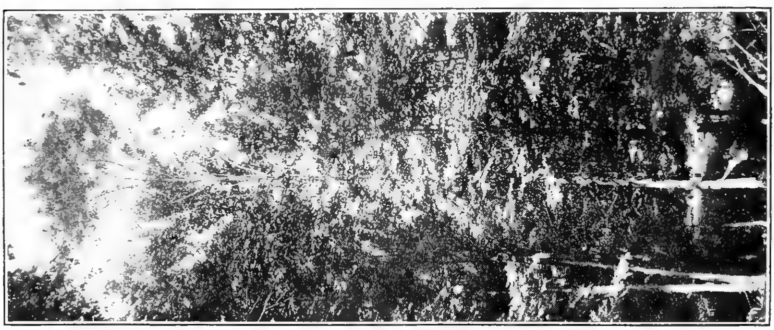
LEATHERLEAF ASH.

F. coriacea is the species commonly named leatherleaf ash, although *F. velutina* is also sometimes so called. The *F. velutina* is the more abundant and occurs chiefly in New Mexico and Arizona, along



F31067

FIG. 1.—Typical long, cylindrical bole of a forest-grown mature white ash in the Southern Appalachians. Characteristically ridged bark.

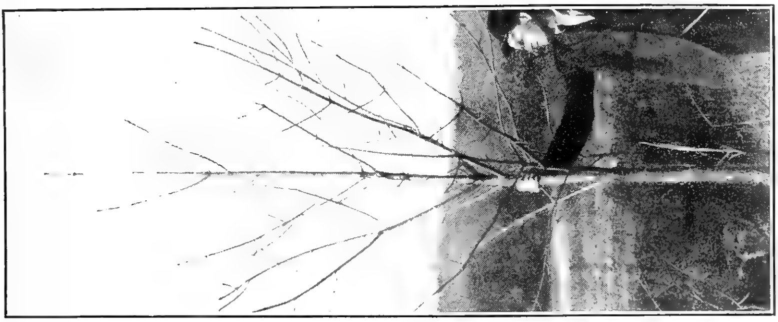


F12527A

FIG. 2.—Long, slim-bodied, short-crowned, codominant white ash in a crowded stand, 45 years old, 8.2 inches in diameter, 68 feet high, in central New York.

F12528A

FIG. 3.—White ash 60 years old and 80 feet high, originally grown in crowded stand, but subsequently isolated by cutting of other trees. The shorter limbs low down are "water sprouts," which have developed since the stand was opened up 10 years ago.



F13353A

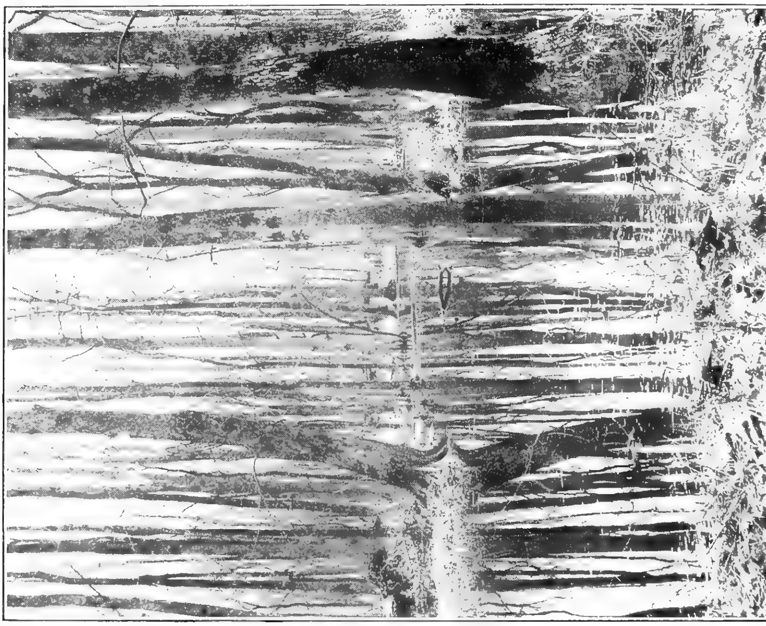
FIG. 4.—Seven-year-old natural Biltmore ash seedling. Shows characteristic opposite branching of ash, and stout twigs characteristic of this particular species.

FIG. 1.—Typical form of blue ash on pastured limestone uplands in Kentucky, 24 inches in diameter, 75 feet high. Note the very heavy crop of seed on tree.

FIG. 2.—Black ash pole with characteristic gray, scaly bark. Tree growing in the hemlock-spruce-balsam-birch-maple type.

F57816

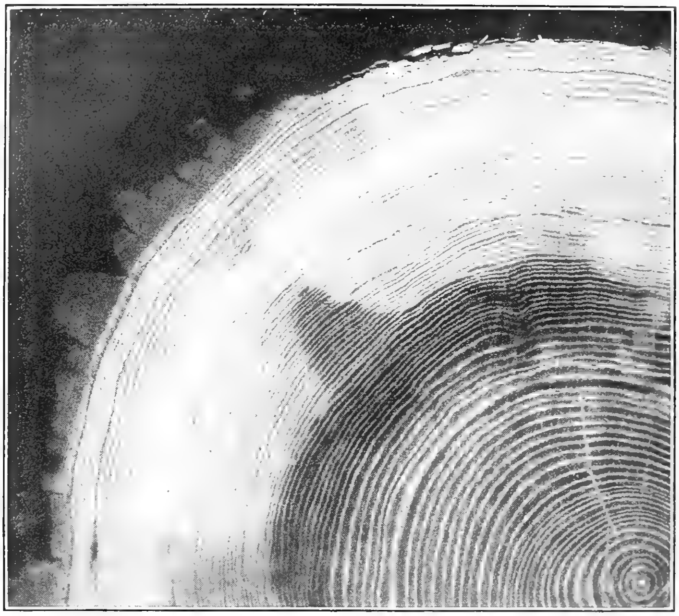
FIG. 1.—Large pole green ash on bottom land overflowed only at high water. Associated with red gum, red maple, hackberry, and sycamore.



F6883

FIG. 2.—Green ash near edge of slough-bottom type (continuously wet land) in mixture with pumpkin ash and cypress (in the background).

GREEN ASH IN NORTHEASTERN ARKANSAS.



F95257

FIG. 1.—Disk from 85-year-old white ash from clay forest soil in central New York. Shows ability to endure long period of suppression and good recovery after removal of large trees 12 years ago. Note ridged bark and irregular line of heartwood. The slow-growth wood in section is weak and not suitable for handles.

F57835

FIG. 2.—Green ash logs cut on overflow bottom land in northeastern Arkansas, very much checked after lying in the sun several months. Characteristically ridged bark.

streams and canyons from 4,000 to 8,000 feet above sea level, with walnut, cottonwood, boxelder, maple, and sycamore. *F. coriacea* occurs chiefly in desert regions of Nevada and southern California on low mesas (ash meadows) and in canyons; also in southern Utah and northern Arizona.

BLACK ASH.

Black ash is primarily a wet-soil swamp tree of northern lowlands and foothills. Its chief commercial occurrence is in the hemlock type (75 per cent of the merchantable stand being hemlock) of the northern half of the Lake States, where it often forms 5 to 10 per cent of the original merchantable stand, averaging 500 to 1,000 board feet per acre. Single forties may average 2,000 feet of black ash per acre, or about 20 per cent of the merchantable stand, and in very wet places single acres of nearly pure black ash (black-ash swamps) sometimes will cut over 5,000 feet. Associated with the hemlock and black ash on this type are hard maple, yellow birch, basswood, elm, white ash, balsam, spruce, tamarack, and arborvitæ and in the southern part of the Lake States beech, white pine, and soft maple as well. All of these species associate more or less with black ash in the Middle and New England States, where the ash is found chiefly in swamps at an elevation of 500 to 1,500 feet above sea level, but rarely forms more than from 1 to 2 per cent of the merchantable stand. In central Indiana and Ohio its coniferous associates disappear, and it has only an occasional botanical occurrence on wet land with such species as willow, sycamore, soft maple, and pin oak. South of Pennsylvania and Ohio black ash is of no importance whatever, having only an occasional botanical occurrence, chiefly in cold mountain swamps, with balsam, spruce, and hemlock.

BLUE ASH.

This upland form of black ash has adapted itself to dry limestone soils under the shade of oaks and hickories, where moisture, humus, and soil conditions are favorable. It occurs primarily on uplands in the oak type in Ohio, Kentucky, Tennessee, and Indiana.

WATER ASH.

F. caroliniana and *F. pauciflora*.—These are deep-swamp species of the south Atlantic and Gulf Coastal Plain region from Virginia to Texas.

SOIL, MOISTURE, AND LIGHT REQUIREMENTS.

SOIL AND MOISTURE.

Ash as a genus is fastidious and exacting in regard to soil fertility and soil moisture. It is not exacting in regard to atmospheric moisture or the amount of annual rainfall, its chief requirement being a soil comparatively moist during a considerable part of the growing season. It is exacting in regard to mineral food in the soil and is somewhat exhausting to it. It does well on rich, loose, limy, or marly soils, and some species even on dry limestone soils. It does not do well on binding or argillaceous soils or on dry sand. On porous soils which offer no hindrance to the developing root system it is as a rule less exacting in regard to surface moisture and fertility than it is on stiff impermeable soils. Ash is adapted, some species more than others, for growing in swamps provided the soil is not acid and there is no turf, but it prefers a rich, moist soil which has a rapid renewal of the water through either surface or subterranean drainage.

Although all species of ash thrive best on moist, well-drained, fertile, porous soils, yet the different species vary in their ability to grow on very wet or on dry soils. The important wet-soil species, in the order of their relative capacity for growing on wet sites, are water, black, pumpkin, and green ash, while the species which will endure dryness of soil (east of the Mississippi) are, in the order of relative capacity, blue, Biltmore, and white ash. West of the Mississippi the green ash forms in the fertile prairie and plain States (where red and green ashes run together) are very enduring under dry conditions, as are also the southwestern species of the green ash group.

LIGHT.

Ash is a light-demanding tree, except for the first few years, during which it does best where the soil is shaded. In youth it is more tolerant than oak and reproduces itself well under a comparatively dense forest cover, because this provides, usually, suitable soil-moisture conditions. The seedlings here show great persistence and tenacity and are able to survive for some time. As an underwood in broken forests seedlings thrive well. After the pole stage, however, ash becomes very light-demanding and space-demanding, especially in pure stands, which is a natural result of its wide-spreading, soil-exhausting root system. The relative intolerance of ash is less apparent because it is most often found on moist fertile soils where trees of all kinds have their greatest tolerance. The effects of even slight shading or crowding on the side is at once apparent in long, clear, thin, spindly boles and small crowns. Ash often shows, however, excellent persistence under unfavorable light conditions, although making no substantial growth, and is quick to recuperate and respond to increase in light. The extreme sensitiveness of ash in this respect is one of the things which commend it for forest management.

Blue, black, and white ash are the most tolerant and persistent under adverse light conditions, and green and pumpkin ash the least so.

REPRODUCTION.

Ash reproduces itself well by seed and by sprouting from stumps of trees cut (Pl. XIV), the first, however, being by far the most important in perpetuating the species.

SEED PRODUCTION AND DISSEMINATION.

Ash of any species, in any region where it is common, usually seeds freely about every other year, and bears some seed almost every year. Exceptionally heavy crops occur at intervals of from three to five years. Not all ash trees are capable of bearing seed, since species of the white and green ash groups are diœcious; that is, male and female flowers are borne on separate trees and seeds occur only on the female trees. Trees in the open are apt to seed when from two to three inches in diameter and from 10 to 20 feet high, being only 10 years old, or even less. In dense stands ash commonly seeds but little until the stand is from 30 to 50 years old and is beginning to thin out. Small-crowned, suppressed, intermediate, and co-dominant trees produce little or no seed; dominant, large-crowned trees and open-grown trees are prolific seeders. Those of the green ash group are the most prolific, seeding when younger and smaller, and more frequently and heavily. White ash is next in this respect and black ash last.

The lightness of ash seed and its long membranous wing allow it to be carried long distances by the wind. Of the important species green ash is disseminated most widely by the wind, white ash is next, and black ash last. The distance depends largely on the weight of the seeds, which is given in Table 5.

TABLE 5.—*Weight of ash seed of different species.*

Species.	Number of seed per pound.			Remarks.
	Low.	High.	Average.	
Fraxinus americana and *F. biltmoreana* [1]	8,500	11,500	10,000	Seed and kernels float in water.
F. lanceolata and *F. pennsylvanica* [2]	12,000	20,000	16,000	
F. nigra, F. excelsior, and *F. quadrangulata.*	6,000	8,000	7,000	Seed (with wing) floats in water, but kernels sink.
F. velutina			14,000	
F. oregona			10,000	
F. profunda	3,000	4,000	3,500	

[1] Biltmore averages the heavier of the two.
[2] Pennsylvanica averages the heavier of the two.

GERMINATION AND SEED-BED REQUIREMENTS.

There is great variation in the germinative characteristics of the different species of ash. Experiments [1] with good, sound, untreated

[1] Seed planted in flats in the Arlington Experiment Station greenhouse in Jan., 1913.

ash seed planted under favorable conditions gave the following results: (1) Green, red, Oregon, and pumpkin ash seed germinate freely in from four to five weeks; (2) Biltmore ash germinates freely in from six to seven weeks; (3) white ash feebly in five months; (4) black, blue, and European ash [1] not at all the first year. The relative perishability of the seed of these species seems to be inversely proportional to the time required for them to germinate, the green ash group being the most perishable and the black the least. Seed of the black ash type has a germinating period of from one to three years. The white and black ash seed can be made to germinate more rapidly by the method described further on in this bulletin.

Ash seed is especially exacting in its moisture requirements for germination and seedling establishments, and reproduction is restricted to spots where the soil or the humus or leaf litter are liberally supplied with moisture at the proper season of the year. Only a limited amount of light (which need not be direct) is required for reproduction. A moderately open seed bed is sufficient; i. e., a layer of undecomposed leaf litter less than 2 inches thick with humus fairly decomposed beneath. Leaf litter and humus serve to keep the ground moist, but they must not be so thick as to prevent the roots of the recently germinated seedling from coming in contact with the soil.

Ash reproduction is most common where the soil is protected from the drying influences of sun and wind, and where at the same time there is some light to decompose the leaf litter more rapidly than is possible in dense stands; for instance, in small openings in the forest where the light is direct or in pure second-growth white pine stands where considerable indirect light reaches the ground. On large, open areas, bare of protecting leaf litter or shrubby plants and weeds, ash reproduces only along streams and river bottoms and in damp depressions. On uplands reproduction is confined mostly to sites where the soil is well protected.

White ash reproduction is often found in upland forests under shade; even in the mixed oak and chestnut type the species will be found reproducing itself in places where the overhead cover is slightly broken. White ash seedlings are remarkably persistent. They maintain themselves in a stunted condition under the shade of large trees for from 5 to 20 years, dying off almost yearly in the hot part of summer or being eaten off by game or cattle and sprouting again the following season. These are called seedling sprouts. Under favorable soil and moisture conditions in the birch-beech-maple-basswood type and the yellow poplar type ash reproduction

[1] Belongs botanically to the black ash group.

occurs under dense shade; ash seedling sprout root systems 10 to 15 years old are often to be found here. If the large trees are cut, the ash seedlings (or seedling sprouts, as the case may be) will usually grow, but can keep pace with the more rapid growing oak and chestnut sprouts only where soil conditions are exceptionally favorable. Pure second-growth white pine stands form an ideal seed bed for white ash and often abound with ash seedlings and seedling sprouts which furnish an excellent basis for a valuable future admixture of ashes when the crop of mature pine is removed.

In general, natural reproduction of white ash is good—that is, the proportion of white ash increases in second-growth stands following lumbering, especially where clean cutting is practiced. It also seeds in well following fire when seed trees are in the vicinity and are seeding at that time.

Natural reproduction of green ash on river bottom land is also good, and it tends to hold its own or to increase in amount in second-growth stands. Green ash is by far the best species for reproducing on old fields because of its quick germination; it does especially well on moist, old-field bottom land, and on hog-rooted pastures.

Natural reproduction of black ash is not so good; the late germination of the seed makes it more liable to be destroyed and the small amount of seed produced decreases its chances of finding favorable sites for germination.

SEEDLING DEVELOPMENT.

Table 6 indicates the rate of growth of ash seedlings under favorable conditions.

TABLE 6.—*Rate of growth of ash seedlings under different conditions.*

Age.	Height.			
	Green ash on old field, South Carolina bottom land.	Green ash in the forest under half shade, Arkansas bottom land.	White ash in the forest, Ohio under half shade.	White ash clean-cut forest, Massachusetts and New York upland.
Years.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	2.8	1.7	0.5	0.5
2	7.0	3.2	1.2	1.6
3	12.2	4.5	2.0	3.0
4	....	5.7	3.0	4.6
5	....	6.7	4.0	7.0

A seedling that has existed in suppression for a number of years will usually start to grow, when the forest is opened up, at about the rate given in the table. Seedling sprouts do especially well when given increased light, and often grow much faster than do ordinary seedlings, because of the large root system they have developed.[1]

Seedlings and seedling sprouts under shade develop slowly. Sometimes the root system is 15 years old and the tree less than 1 foot high. After the first year the seedling demands direct overhead sunlight for best development, but a certain amount of protection on the sides is beneficial.

SPROUT REPRODUCTION.

Ash is a free sprouter from early youth and usually retains its sprouting capacity until old age (see black ash sprouts, Pl. XIV, fig. 2), especially in vigorous trees. The sprouting is both from near the root collar and higher up on the stump. The stump soon decays. Sprouts from near the root collar usually form new roots, and for this reason cutting of low stumps is very desirable in order to limit the reproduction to sprouts of the best kind. It is also a good plan to remove the less vigorous sprouts from a stump in late summer of the first year so as to concentrate the growth into one, two, or three of the more desirable ones.

The vigor of the sprouting increases with the age and size of the tree up to a certain point, after which it falls off. The following measurements [2] on white ash emphasize this point:

Diameter of stump.	Per cent of stumps sprouting.	Basis.
Inches.		*Stumps.*
1 to 4	100	52
5 to 8	100	
9 to 12	83	
13 to 16	80	

White ash sprouts from stumps of healthy trees over 3 inches in diameter grow from 3 to 7 feet the first year, and from 2 to 4 feet a year for several succeeding years. Seedling sprouts, on the other hand (from small seedling root systems), sometimes grow no faster

[1] Measurements by Prof. E. E. Carter in 1912 on two sample plots on the Harvard Forest at Petersham, Mass., gave the following comparative figures on the growth of white ash seedlings and seedling sprouts after clear cuttings in dense mature stands of white pine, under which there was considerable seedling reproduction of ash, ½ foot to 4 feet high, and 5 to 40 years old.

Plot 1.—Seedling sprouts from seedlings cut off at the ground 3 years previously, when the mature stand was cut clean, showed an average total height growth of 4.8 feet in the three years, while seedlings which were not cut back grew only 3.6 feet.

Plot 2.—Seedling sprouts from seedlings cut off at the ground 4 years previously, when the mature stand was cut clean, showed an average total growth of 5.9 feet in the 4 years, while seedlings which were not cut back grew only 4.8 feet.

These plots indicate that cutting off of ash seedlings to facilitate logging operations is beneficial rather than harmful to ash reproduction. The seedling sprouts grew one-third faster than the old seedlings, which means that in addition to straighter stems being produced their chances of getting up out of the reach of browsing stock and deer are much better, which is an important factor in parts of New England and New York.

[2] Measurements taken by J. G. Peters, Hyde Park, N. Y.

when the forest is opened up than do ordinary seedlings; this depends entirely on the relative vigor of their root systems.

Trees of the green ash group are especially vigorous sprouters.

SUSCEPTIBILITY TO INJURY.

STORMS.

Ash is comparatively windfirm under normal conditions, as it develops a wide-spreading, very fibrous, and tenacious root system. Trees of small diameter, with long, slim bodies, left exposed to the sweep of storms after removal of the larger trees, are sometimes uprooted by wind before they have a chance to become windfirm. Also trees located in flood areas of streams are liable to be wind thrown when the soil is badly washed away from around their roots.

The stems of ash trees are strong and elastic and are not subject to windbreak unless infected with heart rot. As the twigs are somewhat brittle, the crowns are sometimes damaged by storms, especially when covered with sleet, but such damage is usually not serious and recovery is rapid.

FROST.

The leaders of ash seedlings growing in the open are sometimes cut back by late spring frosts which follow a growing period of several weeks, but after the trees attain a height of 5 or 6 feet this danger disappears. Ash seedlings readily recuperate from frost damage, but often form double leaders as a result of the injury. Seedlings of American ashes seem to be less subject to frost damage in Europe than native European ash, because they leaf out later. There is considerable variation in earliness of leafing among the different species and among seedlings of the same species grown from seed from different localities. This is important in the culture of ash stands on sites subjected to late frosts. Seeds should be collected, if possible, in the same latitude or to the north of where the planting is to be done.

DROUGHT.

The ashes, except black, pumpkin, and water ashes, offer good resistance to drought when once well established on fertile soils. This is due to their development of numerous long and fibrous lateral roots. Though their rate of growth is very quickly checked by droughty conditions and their leaves soon wither and fall, they live persistently through successive seasons of drought. On the arid plains of western Kansas and Nebraska green ash survived on abandoned timber claims where nearly all other species withered and died. Young ash seedlings are quite susceptible to drought, up to 3 feet high, but by the time they are 5 feet high they have usually developed sufficient root systems to be fairly drought resistant.

Black ash growing in swamps seems to be quickly affected by drainage, and there are large quantities in gradually draining swamps in New York and the Lake States either dead or dying. Excessive transpiration kills these trees down from the top.

In the culture of ash on sites subject to drought, plants from seeds of drought-resisting trees should be used, and the area cultivated for several seasons till good extensive root systems are developed.

ANIMALS.

The tender young shoots and leaves of small ash seedlings and sprouts form unusually attractive browsing for wild animals, especially deer and cattle, which greatly reduces natural reproduction of the genus and causes double leaders on many trees. Trees whose crowns are above browsing distance are practically free from damage by animals.

DISEASES.

Ash is not subject to extensive damage by diseases, which is an important point in its favor. Only one (white rot) has done much serious harm, though a number have been found on the different species. Diseases on ash are confined for the most part to trees whose vitality has been weakened by old age, fire, or generally adverse conditions. Ash stands grown under proper methods of forest management should be practically immune from serious attacks.

White rot occurs in the heartwood of the trunk and main branches, and is caused by the fungus *Polyporus fraxinophilus*, which turns the wood into a mass of yellow pulp. This disease is common in overmature green ash in the lower Ohio and Mississippi River bottoms, near their confluence; also on white ash near the western limit of its range in Iowa, Missouri, Kansas, and Oklahoma, on dry limestone hills, where 90 per cent of the trees are infected.[1] The ash-leaf rust, *Æciduim fraxini*, is probably the most common fungous parasite, occurring on almost all species of ash, but doing little or no serious damage. Other fungi appear on ash leaves and twigs, but rarely in sufficient numbers to do serious injury to the trees affected. Among them are several species of *Glœosporium* and *Sphæropsis*, as well as *Septoria fraxini*, *Phyllosticta fraxini*, and *Sphæronema spina*.

INSECTS.

During the last several years the oyster-shell scale (*Lipidosaphes ulmi*) has increased so much on ash trees in northern Ohio as to kill off entire stands, and is still on the increase in that locality. There are a number of other insects which attack standing ash, but none

[1] Full discussion of this disease in Bulletin No. 32 of the Bureau of Plant Industry, "A Disease of the White Ash caused by Polyporus fraxinophilus."

are very harmful, except the ash-tree borer, which is serious and lessens the value of the wood for lumber.

A large number of insects attack recently felled ash timber. These include a bark beetle, *Hylesinus aculeatus*, which also occurs in dying standing trees; ambrosia beetles or pin borers (*Platypus* and *Xyleborus*); a roundheaded borer, *Neoclytus capria*, destructive to sapwood of recently felled trees; and the powder-post borers, which attack seasoned sapwood. By quick conversion of the felled tree into lumber and by proper methods of handling, seasoning, and storing, losses of logs and lumber through insects can be nearly eliminated.[1]

There should be little or no danger of serious insect attacks on young ash stands under management; nevertheless, the timber owner should be on his guard, and if insects show signs of becoming destructive, he should communicate with the Bureau of Entomology, Department of Agriculture, Washington, D. C., for advice on the subject.

FIRE.

Small ash trees are easily fire-killed because of their thin bark. With increasing size and age ash becomes thicker barked and more fire resistant. Table 24, showing the thickness of bark of trees of different sizes and species, indicates their relative fire resistance (see Appendix, p. 53). Small ground fires, which do not kill standing timber outright, are especially weakening to ash and lessen its rate of growth because of damage to its surface-feeding root systems. It is especially important to keep fire out of young stands.

FORM AND DEVELOPMENT.

Ash is a graceful and beautiful tree, whether growing in the forest or alone as a shade or ornamental tree. Its compound pinnate foliage and symmetrical and regular branching (Pl. VIII) show to advantage in contrast with the foliage and branching of the hardwoods with which it commonly associates.

Ash varies considerably in form and rate of growth in accordance with the character of the site, the amount of growing space, and the species. In general, on favorable sites and under normal forest conditions, dominant ash trees with crowns receiving some direct sunlight on the sides and full light on the tops grow rapidly in both diameter and height, reaching a height of 60 to 80 feet and a diameter of 10 to 20 inches in 40 years. Crowding on the sides, such as codominant and intermediate trees are subjected to, cuts down the rate of diameter growth and increases the clear length, but seems to have little or no effect on the height growth, which persists and is only appreciably lessened by the tree becoming overtopped. In

[1] See Circular 128, Bureau of Entomology, U. S. Dept. of Agriculture: "Insect Injuries to Forest Products."

the open, diameter growth is more rapid, but the tree develops only a very short trunk and large, wide-spreading lateral branches, and is very much inclined to fork, all at the expense of growth in height, and of length, clearness, and cylindricity of bole. Unfavorable sites make themselves at once apparent in a lower rate of height growth in dominant trees. The boles are shorter, more apt to be crooked, and more branchy. In mixed natural stands on such sites ash is usually a spindling, overtopped tree.

In original forests, ashes from 200 to 300 years old, 3 to 5 feet in diameter, and from 125 to 175 feet in height were formerly common, but now 3 feet in diameter is exceedingly large. White ash attains greater height than black or green ash, but is surpassed in diameter and age by black ash. Green ash grows larger in diameter than white ash, but does not become so tall nor live so long.

Crowns of dominant ash trees growing in the forest occupy usually one-third to half the total height of the tree, more on young trees and less on old trees. During the period of rapid height growth, which continues till the tree is from 40 to 60 years old, the crown is rather narrow in proportion to its length and more or less cone shaped; as its age increases it broadens out and becomes dome shaped, and in old age comparatively flat. In youth the crown is considerably longer than it is wide, but this changes with age until the width is greater than the length. Trees crowded on the sides have short, oppressed crowns, often occupying less than a quarter of the total height. (Pl. VIII, fig. 2.)

Ash, because of its intolerance, prunes itself readily when growing in the forest, and develops long, clear, straight boles commonly free of branches for half its total height. The boles have usually a comparatively rapid taper (Tables 25 to 29). Ash trees which have grown under very crowded conditions often have clear lengths of two-thirds or more of their total height.

The species vary somewhat in their characteristic forms as a result of their relative tolerance. Blue (Pl. IX, fig. 1), black, and water ashes have the most persistent limbs and the shortest clear lengths, develop "water sprouts" under lesser light conditions, and for this reason are less desirable to grow (on good sites at least) than white, Biltmore, green, and red ashes.

TABLE 7.—*Rate of growth of white ash on uplands in central New York.*

Age.	A. On moist clay soil.[1]				B. On fresh to moist sandy loam.[2]			
	Fast growth.		Average growth.		Fast growth.		Average growth.	
	Diameter breast-high.	Height.	Diameter breast-high.	Height.	Diameter breast-high.	Height.	Diameter breast-high.	Height.
Years.	*Inches.*	*Feet.*	*Inches.*	*Feet.*	*Inches.*	*Feet.*	*Inches.*	*Feet.*
10	2.1	25	1.3	17	2.5	29	1.3	17
15	3.7	38	2.4	27	5.5	42	3.0	27
20	5.3	50	3.5	36	8.2	52	4.5	34
25	6.7	59	4.5	43	10.4	60	5.9	41
30	8.0	67	5.4	49	12.2	67	7.1	47
35	9.2	73	6.2	55	13.9	71	8.3	53
40	10.2	77	6.9	59	15.3	75	9.4	57
45	11.2	81	7.6	63	16.6	78	10.3	61
50	12.0	83	8.3	66	17.7	79	11.2	65
55	12.9	85	8.9	69	18.7	81	12.2	68
60	13.7	87	9.5	71	19.6	81	13.1	71
65	14.5	88	10.1	73	20.4	82	13.9	74
70	15.2	89	10.6	75	21.2	83	14.8	76
75	16.0	90	11.2	77	22.0	82	15.6	78
80	16.7	92	11.7	79	22.8	83	16.5	81
85	17.3	93	12.2	81				
90	17.9	94	12.6	82				
95	18.5	95	13.1	83				
100	19.1	97	13.6	85				

[1] Based on complete analyses of 47 trees, mostly 80 to 100 years old.
[2] Based on complete analyses of 138 trees, mostly 30 to 70 years old.

The root systems of ash are wide-spreading, surface-feeding, very fibrous, and fairly deep-going, those of the more tolerant blue and black ashes being especially deep-going and often developing taproots. Green and pumpkin ashes growing in wet sloughs are usually bell-butted.

The form and volume of ash trees of different species, diameters, and heights are given in Tables 25 to 46 in the Appendix.

RATE OF GROWTH OF COMMERCIAL SPECIES.

WHITE ASH.

Table 7 shows the rate of growth, under favorable natural forest conditions, of second-growth white ash on moist clay upland and on fresh to moist, sandy loam upland in central New York.

Measurements in central New York on second-growth white ash on well-drained, alluvial bottom land, with a moist sandy loam soil, indicate an average rate of growth approximating that of fast growth on upland, sandy loam in the same locality.

The growth of white ash on sandy loam soil averages faster at the outset than on the clay, but it is not so sustained. On the clay site white ash is more tolerant, the stand more crowded, and the growth in diameter of the average tree is necessarily somewhat slower; the better quality of the site, however, is indicated by the greater height attained and by the greater per acre yields. In managed stands of white ash on suitable uplands it would be possible to secure an average rate of growth in diameter and height nearly equal to that of fast growth under natural forest conditions.

Table 8 shows the rate of growth of white ash under less favorable conditions in southern Indiana.

TABLE 8.—*Rate of growth of white ash on fair upland clay soil in southern Indiana, based on 81 trees 62 to 152 years old.*[1]

Age.	Fast growth.		Average growth.	
	Diameter breast-high.	Height.	Diameter breast-high.	Height.
Years.	*Inches.*	*Feet.*	*Inches.*	*Feet.*
10	1.1	19	0.6	8
20	2.5	34	1.6	17
30	4.1	45	2.5	26
40	5.9	54	3.5	34
50	8.2	62	4.6	41
60	10.9	68	6.0	47
70	14.4	73	7.9	52
80	18.4	78	10.3	57
90	22.8	82	13.2	61

[1] The acceleration in growth at about 50 years is due to a thinning of the forest. Measurements taken by W. Stone in 1909.

Table 9 shows the rate of growth of white ash in natural selection forests containing trees of all ages.

TABLE 9.—*Rate of growth of white ash in natural selection forests, based on 179 trees 77 to 303 years in age, east of the Mississippi River, from Tennessee north.*

Age.	Diameter breast-high.			Height.	
	Maximum.	Average growth.	Fast growth.	Average growth.	Fast growth.
Years.	*Inches.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*
10	2.7	0.6	1.6	8	11
20	6.7	1.8	3.9	14	21
30	11.4	3.1	6.8	21	32
40	16.5	4.4	10.1	27	44
50	20.7	6.0	13.6	35	55
60	24.3	7.7	16.9	43	65
70	27.4	9.5	19.8	52	73
80	30.1	11.4	22.5	60	80
90	32.3	13.2	24.9	67	86
100	34.3	14.9	27.1	74	91
110	36.1	16.7	29.1	80	95
120	....	18.2	30.9	85	100
130	....	19.8	32.6	90	103
140	....	21.2	34.2	94	108
150	....	22.7	35.7	98	111
160	....	24.0	....	101	....
170	....	25.4	....	104	....
180	....	26.8	....	106	....
190	....	28.1	....	109	....
200	....	29.4	....	111	....
210	....	30.7	....	113	....
220	....	31.9	....	114	....
230	....	33.1	....	116	....
240	....	34.3	....	118	....
250	....	35.5	....	119	....

It will be seen by comparison with Table 7 that the growth is considerably slower than that of comparatively even-aged second-growth with better light conditions. The fast growth in Table 9 about represents the possibilities under proper management.

GREEN ASH.

Tables 10, 11, and 12 show the rate of growth of green ash on bottom lands of North Carolina, South Carolina, and Arkansas to be very rapid and well sustained. The North Carolina table shows slower diameter growth than the South Carolina and Arkansas tables, because the stand where the measurements were taken was a very dense, even-aged, unthinned young stand; the growth in height, however, was rapid enough.

TABLE 10.—*Rate of growth of green ash* [1] *on overflow river bottoms in Orangeburg County, South Carolina, based on 410 trees 32 to 180 years old.*

Age.	Fast growth.		Average growth.		Maximum old field height growth.
	Diameter breast-high.	Height.	Diameter breast-high.	Height.	
Years.	*Feet.*	*Inches.*	*Feet.*	*Inches.*	*Feet.*
5	2.5	23	1.0	15	....
10	5.3	39	2.4	26	46
15	7.5	49	3.8	34	59
20	9.4	57	4.9	41	71
25	10.2	64	6.0	47	80
30	12.8	69	7.1	52	88
35	14.3	75	8.1	57	95
40	15.7	79	9.1	62	101
45	17.1	83	10.0	66	106
50	18.5	87	11.0	70	110
55	19.8	91	11.9	74	114
60	21.1	95	12.9	78	117
65	22.3	98	13.8	81	120
70	23.5	101	14.7	84	122
75	24.7	104	15.6	88	124
80	25.9	107	16.4	90	125
85	27.1	110	17.3	93	....
90	28.2	112	18.1	96	....
95	29.4	115	18.9	98	....
100	30.5	117	19.7	100	....
105	31.6	119	20.5	102	....
110	32.6	121	21.3	104	....
115	33.7	122	22.1	106	....
120	34.8	124	22.9	107	....
125	35.8	126	23.6	108	....
130	36.9	127	24.4	110	....
135	....	129	25.2	111	....
140	....	130	26.0	112	....
145	....	132	26.7	113	....
150	....	133	27.5	114	....

[1] Measurements taken by K. W. Woodward, 1905.

TABLE 11.—*Rate of growth of green ash* [1] *on old field river bottom land, Iredell County, North Carolina, in a very dense, even-aged, unthinned stand, based on 20 trees 60 years old.*

Age.	Fast growth.		Average growth.	
	Diameter breast-high.	Height.	Diameter breast-high.	Height.
Years.	*Inches.*	*Feet.*	*Inches.*	*Feet.*
10	3.1	32	1.7	25
15	4.7	44	2.7	35
20	6.2	53	3.7	45
25	7.5	61	4.7	53
30	8.7	68	5.6	59
35	9.7	73	6.4	65
40	10.7	78	7.2	69
45	11.6	82	8.1	73
50	12.5	85	8.9	77
55	13.3	87	9.7	80
60	14.1	90	10.5	82

[1] Measurements taken by J. S. Holmes, 1912.

TABLE 12.—*Rate of growth of green ash*[1] *on river bottom land, Mississippi County, Arkansas, based on 394 trees 20 to 160 years old.*

Age.	Fast growth.		Average growth.	
	Diameter breast-high.	Height.	Diameter breast-high.	Height.
Years.	*Inches.*	*Feet.*	*Inches.*	*Feet.*
10	4.0	....	2.1	14
20	7.8	....	2.9	31
30	11.4	....	7.4	45
40	14.6	....	9.7	57
50	17.4	....	11.7	67
60	19.9	....	13.5	76
70	22.1	....	15.3	85
80	24.2	....	17.0	92
90	26.2	....	18.6	99
100	28.1	....	20.1	105
110	29.9	....	21.7	111
120	31.7	....	23.1	117
130	....	....	....	122
140	....	....	....	126
150	....	....	....	130
160	....	....	....	134

[1] Measurements taken by G. M. Homans, 1905.

In growing green ash under management it should be possible to secure an average rate of growth on bottom lands well above the average for growth under natural conditions, but hardly as rapid as the figures for fast growth given in Tables 10 and 12.

On uplands, and farther north and west, the rate of growth of green ash is considerably slower. A green ash plantation on good prairie soil in central Illinois shows an average rate of growth under management no greater than that under natural conditions on southern bottom lands, and in Iowa the growth is still slower. The per acre yield will always be greatest on the well-drained, moist bottom lands of the South, where the greatest density of stand is possible.

Farther west the possibilities of growth are constantly less. The rate of growth in upland plantations in eastern Nebraska is considerably slower than the average for natural bottom land growth in the East.

TABLE 13.—*Diameter and height growth of green ash*[1] *in eastern Nebraska in upland plantations, diameter growth based on 57 trees and height on 216 trees.*

Age.	Average.	Dominant.	Height.
Years.	*Inches.*	*Inches.*	*Feet.*
5	1.1	....	11
10	2.1	....	19
15	2.9	3.3	24
20	3.6	4.5	28
25	4.4	5.6	32
30	5.0	6.5	36
35	5.3	7.1	38
40	5.4	7.5	40
45	5.5	....	41
50	5.6	....	43

[1] Measurements taken by F. G. Miller, 1905.

In this region the growth falls off rapidly after 25 years, and is not sufficiently sustained to make management profitable. On the better classes of sites, however, with moist soils, especially on bottom land, green ash has a fair chance of profitable growth in the Plains States (Tables 47 to 49). On bottom lands in western Kansas and Nebraska, in young natural stands, green ash has been found to average an inch in diameter growth in three to four years, and in planted stands it grows an inch in diameter every two to three years. In planted stands on uplands in the same region green ash takes five to six years to grow an inch in diameter.

BLACK ASH.

Table 14 shows the rate of growth of black ash in original all-aged selection forests on typical wet land sites in Michigan and Maine.

TABLE 14.—*Rate of growth of black ash in original all-aged selection forests on wet sites.*

Age.	A. In northern Michigan.[1]					B. In Maine.[2]				
	Diameter breasthigh.			Height.		Diameter breasthigh.			Height.	
	Maximum growth.	Average growth.	Fast growth.	Average growth.	Fast growth.	Maximum growth.	Average growth.	Fast growth.	Average growth.	Fast growth.
Years.	*Inches.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Inches.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*
10	1.0	0.4	0.7	9	12	1.8	0.4	1.1	8	15
20	2.4	1.0	1.7	17	24	4.4	1.1	2.7	15	28
30	3.9	1.7	2.7	26	34	7.2	1.9	4.4	22	38
40	5.5	2.5	3.9	34	44	9.9	2.7	6.3	28	45
50	7.3	3.2	5.2	40	52	12.2	3.5	8.1	34	50
60	9.2	4.1	6.5	47	58	14.1	4.4	9.9	38	54
70	11.1	4.9	7.9	52	63	15.7	5.2	11.5	41	58
80	12.9	5.8	9.3	57	67	17.1	6.1	13.1	44	60
90	14.6	6.7	10.7	61	70	18.5	7.0	14.5	47	63
100	16.1	7.6	12.1	64	73	19.8	7.9	15.7	50	65
110	17.6	8.6	13.5	68	76	21.0	8.9	16.9	52	66
120	18.9	9.5	14.7	70	78	....	9.8	18.1	54	68
130	20.3	10.4	15.9	72	80	....	10.7	19.3	56	70
140	21.6	11.4	17.1	74	82	....	11.6	20.5	57	71
150	22.9	12.4	18.2	76	83	....	12.6	....	60	....
160	24.2	13.3	19.3	78	85	....	13.5	....	61	....
170	....	14.2	20.4	79	86	....	14.5	....	63	....
180	....	15.1	21.5	81	87	....	15.5	....	64	....
190	....	16.0	22.5	82	88	....	16.5	....	66	....
200	....	16.8	23.5	83	89	....	17.6	....	67	....
210	....	17.6	24.5	84	90	....	18.7	....	69	....
220	....	18.5	....	86	....	....	19.7	....	70	....
230	....	19.3	....	87	....	....	20.9	....	72	....
240	....	20.1	....	88	....	....	22.1	....	73	....
250	....	20.9	....	89	....	....	23.3	....	75	....
260	....	21.7	....	90	....	....	24.6	....	76	....
270	....	22.5	....	91	....	....	....	....	....	....
280	....	23.3	....	92	....	....	....	....	....	....
290	....	24.1	....	92	....	....	....	....	....	....
300	....	25.0	....	93	....	....	....	....	....	....

[1] Based on 90 trees 79 to 292 years old. [2] Based on 45 trees 85 to 242 years old.

This growth is much slower than can be expected of second growth on land with fair drainage. Black ash planted on uplands in Illinois has been found to grow as fast or faster than white ash.

OTHER SPECIES.

Limited measurements on the less important species of ash indicate the following points:

Biltmore ash grows as fast or a little faster in youth than white ash on similar sites but is not so long lived.

Pumpkin ash on the same site with green ash grows somewhat faster, during youth at least, but is not so persistent. Red and Oregon ashes grow about the same as green, or a little faster, on similar sites.

Blue ash on upland grows much faster than black ash in its natural swamp habitat and nearly as fast as white ash on the same site with it.

PERIODICITY OF GROWTH.

It has been found in southern Indiana [1] that ash does practically all of its growing during the first part of the season—that is, before the 1st of July—which is probably true generally of the genus throughout its range; the latter half of the season it hardens the wood put on, forms tissues, and stores up energy to be used the next season. These facts indicate the importance of cultivating planted stands during the first part of the season.

COMPARATIVE RATE OF GROWTH OF ASH AND ITS ASSOCIATES.

White and green ashes are comparatively rapid growing on favorable sites but very slow on poor sites. On good land white ash may be ranked after black cherry, yellow poplar, chestnut, and basswood in comparative rate of growth, in the same class with red oak or ahead of it (in youth especially), and ahead of white oak, the hickories, birch, beech, and maple. Green ash on bottom lands in the South with sufficient drainage is less rapid growing than cottonwood, willow, sycamore, and elm but about the same as red gum and the faster-growing red oaks and more rapid than the white oaks, red maple, hickories, black gum, and cypress.

As the prevailing occurrence of black ash is on unfavorable wet soils, its growth is slow but no slower than other northern hardwoods on similar sites.

Pumpkin and water ashes also prevailingly occur on very wet soils, where their growth is slow but not below the average for associated species on that type of land.

Blue ash grows more slowly than walnut and yellow poplar, as fast as the oaks on limestone uplands, and faster than the hickories.

YIELD OF PURE STANDS OF ASH.

Although pure stands of ash are very rare, the only way to get an adequate idea of possible yields per acre under management is by the study of yields per acre of pure stands.

[1] Measurements by Forester Deam, of Indiana, on planted stands of white and green ash.

F12531A

FIG. 1.—Thirty-five-year-old natural second-growth white ash cut for handles.

F4199A

FIG. 2.—Forty-year-old green ash plantation at Champaign, Ill., which will cut 8,000 board feet per acre.

SMALL SECOND-GROWTH ASH VALUABLE FOR HANDLES.

F23732

FIG. 1.—Stand in Indiana 15 years old, trees 3 to 6 inches in diameter and 25 to 35 feet high. Not yet ready for thinning, as natural pruning has not progressed far enough.

F13922A

FIG. 2.—Stand 35 to 40 years old in central Ohio. Trees 6 to 12 inches in diameter and 50 to 60 feet high. Stand will cut 7,000 board feet per acre. Natural pruning has progressed sufficiently to admit of heavy thinning if desired. A slight admixture of other species in the stand, including black cherry, yellow poplar, red oak, and sugar maple. Large tree on left is black cherry, which has considerably outgrown the ash, and tree on right is red oak, which, on the other hand, has been outgrown by the ash.

EVEN-AGED, WELL-STOCKED NATURAL STANDS OF WHITE ASH DESIRABLE TO SECURE IN MANAGEMENT.

Table 15 is the result of tabulating the yields per acre of 63 sample plots in comparatively pure, even-aged stands of ash, half in natural and half in planted stands, from 5 to 75 years old, and drawing three curves to represent high but not the highest (Quality I), average (Quality II), and low (Quality III) yields. The stands represented were mostly on average-quality ash sites. Practically all were unthinned stands, and the yields may be considered as representing conservatively the possibilities of well-stocked ash stands under management on fair to good sites.

TABLE 15.—*Yield of pure, even-aged, well-stocked stands of ash on different quality sites.*[1]

QUALITY I.

Age.	Number of trees per acre 3″ and over.	Average diameter breasthigh 3″ and over.	Yield per acre. Scribner Decimal C 7″ and over.	Yield per acre. 3″ and over.	Yield per acre. Cords.
Years.	*Number.*	*Inches.*	*Board feet.*	*Cubic feet.*	
20	427	5.4	2,000	2,200	24.4
25	391	6.5	4,200	3,100	34.4
30	375	7.5	6,500	3,900	43.3
35	361	8.3	9,000	4,600	51.1
40	341	9.1	11,700	5,250	58.3
45	322	9.9	14,700	5,830	64.8
50	288	10.5	18,000	6,350	70.6
55	251	11.2	21,700	6,800	75.6
60	224	11.8	25,700	7,220	80.2
65	203	12.4	29,500	7,600	84.4
70	188	13.0	32,800	7,950	88.3
75	176	13.5	35,600	8,280	92.0
80	166	14.0	38,000	8,600	95.6

QUALITY II.

20	482	4.0	....	850	9.4
25	435	5.0	1,000	1,680	18.7
30	415	5.8	2,200	2,400	26.7
35	393	6.6	3,600	3,050	33.9
40	378	7.4	5,300	3,630	40.3
45	367	8.0	7,500	4,130	45.9
50	361	8.7	9,900	4,590	51.0
55	350	9.3	12,700	5,000	55.6
60	340	9.8	15,700	5,380	59.8
65	326	10.4	19,100	5,720	66.8
70	309	10.9	22,600	6,010	66.8
75	288	11.5	25,500	6,270	69.7
80	268	12.0	28,000	6,520	72.4

QUALITY III.

25	469	3.5	....	470	5.2
30	456	4.2	....	970	10.8
35	452	4.9	300	1,470	16.3
40	426	5.5	1,300	1,950	21.7
45	410	6.2	2,400	2,400	26.7
50	402	6.8	3,900	2,790	31.0
55	392	7.3	5,600	3,150	35.0
60	382	7.9	7,700	3,470	38.6
65	377	8.4	10,200	3,760	41.8
70	371	8.9	12,900	4,020	44.7
75	365	9.3	15,700	4,260	47.3
80	359	9.8	18,000	4,490	49.9

[1] Based on 18 plots, Quality I, 30 plots, Quality II; 14 plots, Quality III, with a total area of 16.9 acres.

The yield table may be considered as especially applicable to pure, even-aged, well-stocked natural stands of white ash, as 42 of the 63 plots were white ash, 28 of which were in natural stands in New York and Ohio. Fourteen plots in planted white ash stands were taken in Illinois, but did not average quite as high yields as those in natural stands farther east.

Fifteen of the plots were in green ash, 14 of which were in planted stands in Iowa and Illinois and 1 in a natural stand in North Carolina. The average yield possibilities for well-stocked stands of green ash on southern bottom lands free from water during most of the growing season would be considerably above that of Quality II in the table, but probably below Quality I.

Six of the plots were in planted black ash stands in Illinois, which indicated higher yields than planted white ash stands in the same State. These yields, however, are very much too high to be representative of the best well-stocked natural black ash stands in typical black ash swamps of the Lake States.

VALUE OF STANDING ASH TIMBER.

A good way to figure the stumpage in any particular locality is to subtract from the f. o. b. mill value of the manufactured lumber the cost of production plus a reasonable profit to the producer for his time, labor, and capital. The total cost of producing ash lumber usually varies from $10 to $18 per thousand board feet, and on the average is not over $14. Ten per cent of the f. o. b. value of the products is enough to allow for profit in figuring what future ash stumpage grown under forest management will be worth. On this basis Table 16 is constructed, giving for different costs of production the value of standing ash timber, which when cut into lumber will sell (mill run) at the prices indicated. The amount of the producer's profit is also given.

TABLE 16.—*Stumpage values per 1,000 board feet for different f. o. b. mill values and different costs of lumbering (allowing 10 per cent for profit).*

F. o. b. value.	10 per cent profit of producer.	Cost of lumbering.				
		$10.	$12.	$14.	$16.	$18.
Per 1,000 board feet.		Stumpage value per 1,000 board feet.				
$20	$2.00	$8.18	$6.18	$4.18	$2.18	$0.18
22	2.20	10.00	8.00	6.00	4.00	2.00
24	2.40	11.82	9.82	7.82	5.82	3.82
26	2.60	13.64	11.64	9.64	7.64	5.64
28	2.80	15.45	13.45	11.45	9.45	7.45
30	3.00	17.27	15.27	13.27	11.27	9.27
32	3.20	19.09	17.09	15.09	13.09	11.09
34	3.40	20.91	18.91	16.91	14.91	12.91
36	3.60	22.73	20.73	18.73	16.73	14.73
38	3.80	24.55	22.55	20.55	18.55	16.55
40	4.00	26.36	24.36	22.36	20.36	18.36

Ash stumpage, especially small second-growth trees conveniently located, will very often be worth more if made into handles (Pl. XII), baseball bats, oars, etc., than if cut into lumber.

From the standpoint of management the value of second-growth stands is the important thing, and this in turn depends largely on the proportion of grades which any particular stand will cut. Table 17 indicates the percentage of the different grades cut from second-growth white ash under 75 years of age of different diameters from comparatively straight and sound trees, such as would be grown in properly managed second-growth stands.[1] The second half of this table shows the f. o. b. mill-run value per thousand board feet of trees of different diameters, taking the following f. o. b. prices for the different grades:

	Firsts and seconds.	No. 1 common.	No. 2 common.	No. 3 common.
High	$60	$35	$25	$15
Average	50	30	20	10
Low	40	25	15	5

TABLE 17.—*Per cent of grades cut from white ash trees of different diameters, for comparatively straight and sound trees under 75 years old, and f. o. b. mill values of the same.*

Diameter breast-high.	Firsts and seconds.	Grade.			F. o. b. mill value per 1,000 board feet.		
		1 common.	2 common.	3 common.	High.	Average.	Low.
Inches.	*Inches.*	*Per cent.*	*Per cent.*	*Per cent.*			
8	....	53	34	13	$29.00	$24.00	$19.00
10	1	51	41	7	29.75	24.70	19.65
12	7	47	40	6	31.55	26.20	20.85
14	22	42	30	6	36.30	29.20	24.10
16	29	42	22	7	38.65	32.20	25.75
18	35	39	19	7	40.75	33.70	26.95
20	43	36	15	6	42.75	35.90	28.75

Stated in general terms, the mill-run value of second-growth ash from comparatively straight and sound trees of all three commercial species is about as follows:

Size of trees in diameter, breast-high.	Mill-run value per 1,000 board feet.		
	Low.	Average.	High.
Inches.			
7 to 11	$20	$24	$29
12 to 16	24	29	36
17 to 21	28	34	40

[1] Based on a mill scale study made in western New York of the cut by grades of 43 white ash logs from trees 8 to 20 inches in diameter, breasthigh, and 40 to 70 years old.

Applying the foregoing mill-run or f. o. b. values to Table 16, taking $14 as an average cost of lumbering, would give stumpage values as follows:

Size of trees in diameter, breast-high.	Stumpage value per 1,000 board feet.		
	Low.	Average.	High.
Inches.			
7 to 11	$4.18	$7.82	$12.36
12 to 16	7.82	12.36	18.73
17 to 21	11.45	16.91	22.36

These values may appear too high, because in practice the operator is often at present able to purchase his stumpage for less than its real value and accordingly makes more than 10 per cent profit. This state of affairs, however, is rapidly disappearing as the supply of raw material diminishes; and the operator will finally be forced to do business on less rather than on more than a 10 per cent profit basis, especially when it comes to the purchase of second-growth timber grown at some expense under forest management. Further, it must be remembered that the timber grower is not at the mercy of the market so much as the manufacturer and the farmer, because he can more easily hold his goods until better prices obtain.

Probably a record price for ash stumpage was paid in 1913 in east-central Illinois (near the Indiana line) when $32 per thousand board feet was paid for a quarter million feet of old-growth white ash, while on the same tract, $125 per thousand board feet was paid for black walnut, $24.75 for white oak, and $18.05 for hickory.

ADVISABILITY OF FOREST MANAGEMENT OF ASH.

The growing of ash timber, under proper management, will sometimes pay 6 per cent or better on the money invested, where good yields per acre and good stumpage prices are obtained. This is shown by Table 18, which gives the compound-interest rates (where 3 per cent or over) to be realized on different initial investments in growing ash where the yields indicated in Table 15 are obtained and where the stumpage is worth $5, $10, $15, or $20 per thousand board feet.

TABLE 18.—*Interest rates*[1] *(compound) to be expected on money invested in growing ash, where yield quality I, II, or III stands are secured, calculated for different stumpage values and for different initial investments.*

(Blank spaces indicate less than 3 per cent interest.)

Age of stand.	Value of stumpage per 1,000 board feet.	Total initial investment per acre.																	
		$5.[2]			$10.[3]			$15.[4]			$20.[5]			$25.[6]			$30.[7]		
		Compound interest rates (per cent) for yield quality I, II, and III stands.																	
		I.	II.	III.	I.	II.	III.	I.	II.	III.	I.	II.	III.	I.	II.	III.	I.	II.	III.
Years. 20	$5	4.2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	10	7.5	....	....	3.9	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	15	9.6	....	....	5.9	....	....	4.3	....	....	....	....	....	....	....	....	....	....	....
	20	11.1	....	....	7.3	....	....	5.6	....	....	4.1	....	....	3.3	....	....	....	....	....
30	5	6.1	....	....	3.7	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	10	8.8	4.6	....	6.3	....	....	4.9	....	....	3.9	....	....	3.2	....	....	....	....	....
	15	10.3	6.2	....	7.8	3.7	....	6.4	....	....	5.4	....	....	4.6	....	....	4.0	....	....
	20	11.4	7.3	....	8.8	4.8	....	7.4	3.5	....	6.4	....	....	5.6	....	....	5.0	....	....
40	5	5.8	....	....	4.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	10	7.9	5.5	....	6.1	3.7	....	5.0	....	....	4.2	....	....	3.6	....	....	3.1	....	....
	15	9.1	6.8	....	7.3	4.9	....	6.1	3.8	....	5.4	3.0	....	4.7	....	....	4.3	....	....
	20	10.0	7.7	....	8.1	5.8	....	7.0	4.7	....	6.2	3.9	....	5.6	3.3	....	5.1	....	....
50	5	5.3	3.3	....	3.8	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	10	7.1	5.6	....	5.6	4.1	....	4.7	....	....	4.1	....	....	3.5	....	....	3.1	....	....
	15	8.1	6.6	3.9	6.6	5.2	....	5.7	4.2	....	5.1	3.6	....	4.5	....	....	4.1	....	....
	20	8.8	7.4	4.9	7.3	5.9	3.4	6.4	4.9	....	5.7	4.3	....	5.2	3.7	....	4.8	3.3	....
60	5	4.7	3.0	....	3.5	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	10	6.4	5.3	....	5.2	4.1	....	4.3	....	....	3.8	....	....	3.2	....	....	....	....	....
	15	7.3	6.2	4.4	6.0	5.0	3.2	5.2	4.1	....	4.7	3.6	....	4.2	....	....	3.9	....	....
	20	7.8	6.8	5.2	6.6	5.6	4.0	5.8	4.8	....	5.3	4.3	....	4.8	3.7	....	4.6	3.4	....
70	5	3.9	....	....	3.2	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	10	6.4	4.8	....	4.6	3.8	....	3.7	....	....	3.3	....	....	....	....	....	....	....	....
	15	6.5	5.7	4.4	5.4	4.7	3.4	4.6	3.8	....	4.2	3.4	....	3.7	....	....	3.4	....	....
	20	7.0	6.3	5.1	5.9	5.3	4.1	5.2	4.5	....	4.8	4.0	....	4.3	3.5	....	4.0	3.2	....
80	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	10	4.8	3.9	....	3.9	3.0	....	....	....	....	....	....	....	....	....	....	....	....	....
	15	5.6	5.0	3.8	4.7	4.1	....	3.9	3.1	....	3.5	....	....	....	....	....	....	....	....
	20	6.1	5.7	4.7	5.2	4.7	....	4.5	3.8	....	4.1	3.5	....	3.6	....	....	3.4	....	....

[1] Calculated by the formula $p=100\left[\sqrt[n]{\frac{S+L-A}{L+F}}-1\right]$, where p=compound interest rate, n=number of years or rotation, S=stumpage value at n years; L=cost of land; F=cost of formation; and A=cost of administration and taxes in n years at 6 per cent compound interest. Five cents per acre annually is allowed for administration (including fire protection) and one cent on the dollar (full valuation) annually for taxes.

[2] $5 cost of land, and no cost of formation of stand.

[3] $5 cost of land, and $5 cost of formation of stand.

[4] $10 cost of land, and $5 cost of formation of stand.

[5] $10 cost of land, and $10 cost of formation of stand.

[6] $15 cost of land, and $10 cost of formation of stand.

[7] $15 cost of land, and $15 cost of formation of stand.

Where Quality I yields and $20 stumpage are to be obtained, the operator may spend as much as $20 per acre in buying land and establishing a stand of ash and still get 6 per cent interest on the investment. Where Quality II or average yields and $20 stumpage are to be obtained, it is possible to get 6 per cent interest on an investment of $10 per acre. Quality III yields with $20 stumpage will only pay a little over 5 per cent interest on an original investment of $5.

On the average, ash stumpage will be worth only from $10 to $15 per thousand board feet, and well-stocked seedling stands of ash will usually cost $10 or more per acre. On this basis it will require at the least a Quality II yield to pay 6 per cent interest. These figures disregard the possibility of intermediate returns from thinnings, which under especially favorable conditions might amount to from 20 to 30 per cent of the value of the final returns. It may be said in general, however, that growing ash timber as a profitable investment is practically limited to lands which will produce good yields of ash and which do not cost over $10 or $15 per acre.

Ash is one of the most desirable trees for growing in farmers' woodlots, wherever the soil is suitable, because of its usefulness for many purposes on the farm, and because it brings a high price when sold. It is also especially to be recommended for timber growing on agricultural land which the owner does not wish to use or develop at once for agriculture, but which he, nevertheless, desires to hold indefinitely. The cost of growing temporary forest crops which will pay fair returns will be very small in comparison with the cost of developing land agriculturally. Such crops will also require very little supervision. It will often be a wise policy for the farmer to cultivate only so much land as he can handle according to the best farming methods, allowing the rest to grow to timber.

In the management of all forest types in which ash occurs naturally, it is always to be ranked as one of the most, if not the most, desirable species to encourage, often to the extent of securing pure or nearly pure stands of it over limited areas where the soil is suitable.

OBJECT OF MANAGEMENT.

The object of management of ash should be to secure on sites well adapted to its growth either well-stocked, pure, or nearly pure stands; or well-stocked mixed stands of desirable species, ash forming as large a proportion as it is practicable to secure, and being made, by thinnings if necessary, the favored dominant tree with plenty of growing space (Pl. XIII).

Pure stands of ash will usually have to be established by planting or sowing, as only comparatively small patches can be secured by natural reproduction. They should be limited, as a rule, to the best sites and to short rotations, which will insure high yields. On all but the best sites ash is silviculturally better adapted for growing in mixed stands, either singly or in small groups, because the trees are light demanding and develop wide-spreading, surface-feeding root systems, and can be advantageously separated by more tolerant species with deep-growing roots.

ROTATION.

Ash should be grown, as a rule, on comparatively short rotations of 30 to 60 years. Table 18 shows that the best financial rotation, or one which will yield the highest rate of interest on the money invested, falls between these years. The financial rotation is lengthened by low yields, low stumpage values, and high initial investment, while the opposites of these shorten it. The actual rotation in any particular case may be altered from what seems to be the best financial rotation by a number of factors, including the purpose for which the timber is grown, the condition of the market, and the occurrence of seed years.

From a silvicultural standpoint a short rotation is highly advisable for pure even-aged stands of ash, because of the tree's root and crown requirements. Long rotations in pure stands should be practiced only on the best sites, and in some cases where a long rotation is desired the stand should be heavily thinned out and under-planted after it is 40 to 50 years old, to protect the soil. In mixed stands where it is the favored dominant tree ash can often be grown singly or in small groups on a long rotation.

SPECIES FOR COMMERCIAL TIMBER GROWING.

Species of the white and green ash groups are more desirable for commercial timber growing than those of the black ash group, because their wood is superior in mechanical properties and because they are usually faster growing and attain greater length and clearness of bole. There are two classes of sites, however, where for silvicultural reasons it may be advisable to grow ash of the black ash group—namely, blue ash on dry limestone formations of the Central States and black ash in northern swamps.

There is no great variation in the mechanical properties of the different species of the green and white ash groups, and little or none in the sale value of lumber of the same grade from different species, so that the selection of species for commercial growing from these groups depends entirely on their silvicultural qualities. In general, the species which is most common to the region and character of site in question should be used. The growing of species outside their natural habitat (of region and site) should never be tried on more than an experimental scale. White ash will be the species to use, as a rule, in the New England, Middle, Central, and Lake States and in the hills and mountains of the South; and green ash on river bottom land of the Southern, Central, and Plains States. Of very minor importance will be the growing of Oregon ash on the Pacific coast and of leather-leaf ash (*F. velutina*) in the Southwest (the latter for shade, ornament, and protection). Biltmore ash is an important supplementary species to white ash and can be advantageously substituted for it on drier soils in the Central States and in the southern Appalachians at an elevation of from 1,000 to 2,500 feet. Texas ash is the natural substitute for white ash on uplands in central Texas, but is not important for commercial timber growing. Red and pumpkin ash are two excellent substitutes for green ash, the former adapted to somewhat drier soils and more rigorous climate than green (extending farther north), and the latter to somewhat wetter soil conditions in the central and eastern parts of its range.

Possibilities of reforestation by natural reproduction are quite good with white and green ash, but naturally very limited with the other less abundant species.

In planting or sowing ash it is advisable to use seed from trees of species common in the region (and on similar sites, if possible) where the reforesting is to be done, or from a region with a slightly more rigorous climate. Also seed should always be secured, if possible, from vigorous, rapid-growing individuals.

NATURAL VERSUS ARTIFICIAL REFORESTATION.

Wherever it is possible to secure natural reproduction by using such methods as are described later every effort should be made to do so. Artificial reproduction is more expensive and less certain of ultimate success. Planting should be confined to spots where natural reproduction is incomplete or to areas where there is no possibility of natural growth. It will sometimes be more advisable, however, especially on cheap land, to spend money for disengagement cuttings, to liberate the ash and other desirable species from suppression, rather than for supplementary planting work. In other cases it may be well to divide the money to be spent between planting and disengagement work. In general, the more expensive the land and the higher the stumpage values the more profitable will it be to spend money on artificial reproduction in order to secure fully stocked stands with the largest possible per acre per annum growth instead of being satisfied with incomplete natural reproduction at no expense and giving smaller yields per acre. For instance, Table 18 shows that a 5,000 yield on $20 land with no cost of esablishment will not pay as well as a 10,000 yield on the same with $5 to $15 cost of establishment, while on $5 land a 5,000 yield without cost of establishment would pay best. Similarly the less the natural yield capacity of the soil and the lower the stumpage values the less likely is it to be profitable to spend money in establishing a stand.

Adequate reproduction of ash, resulting in highest yields, demands that on every separate square rod of space there should be at the start a minimum of one thrifty ash seedling, together with at least three other good seedlings of ash or other species, an absolute minimum of 160 ash trees per acre spaced about a rod apart each way, and a total minimum of 681 trees per acre of all species. This corresponds roughly to a spacing of 8 by 8 feet. For the sake of safety it is best to have two or more ash seedlings on every square rod at the outset. The important point in production of high per acre yields is, not the total number of ash seedlings per acre but the number of individual square rods on the acre which have ash seedlings on them. It is best therefore to plant the square rod areas having no promising natural reproduction of ash on them.

The total area where natural reproduction of ash is possible is very small in comparison with the possible area where it can be artificially established with success, as it very seldom forms a sufficient proportion of the mature stand to reproduce itself adequately. The principal species for natural reproduction are the most abundant ones, which are white, green, and black ash; the other species, where desired will usually have to be artificially established.

REFORESTING BY NATURAL MEANS.

The methods described here apply to all stands, pure or mixed, where the object is to remove the mature stand in such a way as to secure as much natural reproduction of ash as is possible. Methods of cutting (see pp. 42–44) should be used which will bring about the production and dissemination of as much seed as possible over the area, and which will assist in providing suitable seedbed and light conditions for germination and seedling establishment. In many cases additional work may be necessary, such as cutting out worthless material and underbrush to improve conditions for seeding and seedling growth, and later on when the ash seedlings are several years old disengagement cuttings to free them from crowding or suppression. All possible use should be made of seedlings and seedling sprouts already on the ground, as these will usually recover and grow well when the mature stand is opened up. If such growth is scraggly it can be cut back near the ground and allowed to sprout up again, which is especially advisable where it is over 5 feet in height and even in the case of small poles up to 20 feet in height. The mature trees should be cut with low stumps, so as to encourage sprouting from near the ground (below the root collar), which sprouts will form independent root systems and make the best trees.

Any attempt to secure natural reproduction of ash assumes the occurrence, in the stand to be cut, of ash trees which can be used for seeding purposes. It will often be possible to remove the mature stand in such a way as to secure so abundant a reproduction that ash will be one of the leading species in the new stand, though in the old stand it may form but a very small proportion (Pl. XIV, fig. 1), perhaps only three or four seed trees per acre.

The fact that white and green ash have male and female flowers borne on separate trees will not usually interfere with ash reproduction cuttings, as such cuttings will be made after it is apparent that there is going to be a good seed year, and the tree which will have the most seed can be picked out and reserved. In preliminary reproduction cuttings (to induce seed production) it should be remembered, however, that one large-crowned male tree per acre will pollinate more than enough flowers of female trees on that acre, and the remaining males can be removed if desired. Determination of sex can be made by marking trees which bear seed (female trees) in advance of such cuttings. In mixed stands with a small percentage of ash and where the sexes have not been determined, it will be best to leave all large-crowned ash trees.

METHODS OF CUTTING.

The methods of cutting to secure natural reproduction of ash may be grouped under two general systems; the shelterwood system and the clean-cutting system, the former being adapted to all sites on which ash grows, the latter to a limited range of sites. The best method to use in any particular case depends on a number of factors: The species to be reproduced; the site, especially soil moisture and soil covering; age and density of the stand, including the amount and character of the undergrowth; and proportion of ash in the mature stand.

SHELTERWOOD SYSTEM.

The shelterwood system consists in the more or less gradual removal of the mature stand, allowing reproduction to get well started under the shelter of the mature stand before removing it entirely. This system is especially suitable to upland white ash, as it preserves soil moisture, a liberal amount of which is necessary for germination and seedling establishment. The method of cutting to be used varies with the density of the stand.

In comparatively dense stands the mature trees should be removed in two or three cuttings: First, a seed cutting, often unnecessary, consisting in opening up around ash trees (and trees of other species it is wished to favor) to induce them to seed freely; second, a heavy thinning or partial clearance in the year of good seed production, removing one-quarter to one-half of the volume of the stand; third, removal of the remaining stand a year later or as soon as practicable after reproduction has taken place. Where these cuttings are made with reference to a number of small areas—thinning out around individual trees or small groups of trees of less than a quarter acre in area—which are gradually enlarged until they meet, it is called the shelterwood group method, and where the general cuttings are made uniformly over a considerable area it is known as shelterwood compartment method. The latter method is suitable for comparatively regular forests, while the former is more applicable to irregular forests, including overmature natural forests, and hence is the one to be most often used under present forest conditions. The compartment system is preferable where possible, because it involves less expensive and complex silvicultural and lumbering operations.

In broken or open stands, where ash seed trees occur with comparatively free crowns, the first and second cuttings may be very much restricted or even omitted altogether. There will usually be, however, in such stands obstructing undergrowth which should be removed when there is a good seed year, preferably cut with a brush hook or bolo in the late summer so as to encourage the feeble growth of tender sprouts which otherwise will likely be winterkilled. The mature stand should be removed as soon as possible after reproduction takes place. Much of the black and blue ash seed will lie over and not germinate till the second year, which may delay removal of the mature stand. Previous to the fall of seed much work can be done in the way of preparation of the seedbed, especially where it is thick and dry: (1) Wounding of the soil in logging operations; (2) burning of the forest floor; (3) turning in stock, especially hogs. This kind of work is not necessary when the cover is prevailingly of pine needles, as ash seed can work its way through (Pl. XIV, fig. 1). If reproduction is inadequate at the first seeding it will not pay (except perhaps with green ash) to wait for another seed year, the area should be cut clean at once and fail spots planted up.

CLEAN-CUTTING SYSTEM.

This consists in clean cutting the stand when there is a good seed year at hand. Seed is secured: (1) By making the cutting after the seed has fallen; (2) by making strip or border cuttings 100 to 200 feet wide on the most protected side of the stand, or by clean cutting in patches 100 to 300 feet wide, so that seed may be secured from trees in the adjacent stand; (3) by clean cutting except for scattered seed trees or groups of trees, several good seed trees or groups to the acre if possible, well distributed. Clean-cutting methods are adapted only to moist or wet loamy soils with an open seedbed. Preparation of the seedbed as described for the shelterwood system will often be advisable. Green ash on southern river bottom lands is especially adaptable to this system, but the other species of ash are much less so.

PLANTING OF FAIL SPOTS AND DISENGAGEMENT CUTTINGS.

A year or two after the seeding of a new crop (simultaneously with the removal of the remaining shelter stand under the shelterwood system, or during the first good season for planting which follows) it is very desirable to go over the stand and plant one or more vigorous young ash seedlings in every square rod which has no reproduction of ash or other desirable species. Some places may be covered with a thick growth of inferior species, in the middle of which a square yard or so is cut clean and an ash seedling planted. Other square rods may be fail spots for reproduction of any kind, and here four (approximately 8 by 8 feet) or more seedlings should be planted, but not necessarily all ash.

Another important thing to be done at the time or within five years (the sooner the better) of the final cutting of the remaining mature stand is disengagement work. This consists in freeing the crowns of a certain number of well-distributed and vigorous ash seedlings (and desirable seedlings of other species) from injurious crowding on the sides and from overhead suppression by lopping off the less desirable seedlings with a corn knife or brush axe. At least one well-freed, vigorous seedling should be left on every square rod, and preferably three or four seedlings of desirable species. One man should be able to cover one or two acres a day in this kind of work.

REFORESTING BY ARTIFICIAL MEANS.

Artificial reforestation of ash is expensive, and should be limited to cleared fields and pastures and to the choicer forest sites in the natural habitat of the particular species to be grown.

There are three general classes of artificial reforesting advisable for ash: (1) Planting on cut-over forest areas (including fail-spot planting in naturally reproduced stands); (2) dibbling in or sowing of ash seed under cover of mature stands (with good soil moisture conditions) to be removed the following year, or sowing immediately after clean cutting of stands on moist, fertile, loamy sites free from undergrowth; (3) planting or sowing of cleared areas, including chiefly old fields and pastures. Underplanting of areas to be cut over later will seldom if ever be advisable.

In regard to the question of planting versus sowing, the former is of much more general application and more certain of success; while the latter is much the cheaper, and under some conditions has good possibilities of success.

PLANTING.

Seedlings for planting should be nursery grown, as a rule, since they are cheaper and much more likely to survive than wild stock. Wild stock seedlings might be used locally to a very limited extent for filling in spots, when it is not convenient to get nursery stock, and when it is possible to dig them up from near-by spots where they are unnecessarily thick, and to transplant with great care. Wild stock seedlings to be planted in comparatively open spots must be taken from situations with similar shade conditions. Young (1 to 3 years old), vigorous, straight seedlings, under 2 feet in height, should be secured if possible. For nursery-grown stock 1 to 2 year seedlings, 6 inches to 2 feet high, are preferable because cheaper, more easily planted, and usually more likely to succeed than older and larger stock.

The general spacing for plants on cut-over areas has already been referred to (see p. 41). In general, 8 by 8 feet each way will be all right, with every other tree an ash, although on drier and poorer sites 6 by 6 feet should be used. Where there is danger of suppression by undergrowth or natural growth of any kind, vigorous plants 2 to 4 feet high (2 to 3 years old) should be used, but otherwise plants one-half to 2 feet in height (1 to 2 years old) will be sufficient.

In planting fields and pastures the spacing should be 8 by 8 feet where it is possible to cultivate and to grow field crops several seasons between the rows; where not cultivated, 6 by 6 feet spacing (or 5 by 5 if soil is dry) should be used, except on unusually moist fertile soil, where 7 by 7 or 8 by 8 is all right. It is possible to plant as few as one-quarter of the trees ash, and by subsequent favoring to make them form practically a pure stand. In this case every other row could be of another species, and the remaining rows of ash alternating with another species, which would result in the following number of ash trees for the different spacings:

Spacing.	Total plants per acre.	Ash plants per acre (one-quarter of the total.
Feet.		
5 by 5	1,743	436
6 by 6	1,210	303
7 by 7	889	222
8 by 8	681	170

Table 19 gives the species suitable for planting with ash.

TABLE 19.—*Species for planting in mixture with ash.*

Site.	Species of ash to be planted.		
	White ash. Biltmore ash.	Green ash. Red ash.	Black ash.
	Best species to plant in mixture.		
Fresh to dry	Hard maple.[1] White pine.[2] Black locust.[1] Red oak.[2] Beech.[1] European larch.[2]	White pine. Silver maple. Russian mulberry.[1] Red oak.[2] European larch.	
Moist to wet	White pine. Silver maple.[4] Cottonwood.[3] Yellow poplar.[3]	Cottonwood.[3] Willow.[2] Red maple.[1] Loblolly pine.[2] Cypress.[2] Yellow poplar.[3] Pin oak.[2]	White pine. Spruce. Larch. Elm.
Swamp	....	....	Spruce.[2] American larch.[2] Elm.

[1] Secondary tree; not liable to overcrowd ash.
[2] Principal tree; not liable to overcrowd ash.
[3] Principal tree; liable to overcrowd ash, and should be sparingly planted and given plenty of room in mixture with ash.
[4] Secondary tree; liable to overcrowd ash and should be thinned out subsequently where necessary, or cut back and allowed to sprout up again.

The general rule should be to cultivate the planted ash stands twice a season for two or three seasons wherever practicable (Pl.XV), except, perhaps, on the best moist, fairly well drained, permeable loamy sites, such as fertile alluvial river bottoms, where the trees will take hold and grow well without cultivation.

COST OF PLANTING.

The cost of planting on unprepared sites, where plowing or cultivation of any kind is impracticable, will range about as follows:

Cost of seedlings (delivered at the site)	$2 to $6, average $4 per 1,000
Cost of setting	3 to 9, average 6 per 1,000
Total	5 to 15, average 10 per 1,000

This is figuring that one man at $1.25 to $2 per day will plant 200 to 400 seedlings per day. Home-grown seedlings could often be produced for less than $2 per 1,000, so $4 for average cost per 1,000 of seedlings is conservative.

Using $10 per 1,000 (a very liberal amount to allow even for cut-over forest land) for cost of plantations, their cost per acre for different spacings would be as given in Table 20.

TABLE 20.—*Cost per acre of establishing ash plantations on unprepared ground with cost of plants $4 per 1,000 and cost of setting at $6 per 1,000.*

Spacing ....feet..	8 by 8.	7 by 7.	6 by 7.	6 by 6.	5 by 5.
Number of plants	681	889	1,038	1,210	1,743
Cost of plants	$2.72	$3.56	$4.15	$4.84	$6.97
Cost of setting	4.09	5.33	6.23	7.26	11.46
Total	7.81	8.89	10.38	12.10	17.43

Wherever possible it is advisable to prepare the land by plowing. The cost of setting the seedlings on prepared ground will be much less—not over $2 to $3 per 1,000—while the growth of the seedlings will be much increased and the number of failures much reduced. The total per acre cost of plantations of different spacings on prepared ground, allowing $2.50 per 1,000 for cost of setting, $4 per 1,000 for the plants, and $1 to $6 for cost of preparation and subsequent cultivations, is shown in Table 21.

TABLE 21.—*Cost per acre of establishing ash plantations on prepared ground with subsequent cultivations, seedlings to cost $4 per 1,000 and $2.50 per 1,000 for setting.*

Spacing.	Number of trees.	Cost per acre of preparation and cultivation.					
		$1	$2	$3	$4	$5	$6
		Total cost of plantation per acre in dollars.					
Feet.							
8 by 8	681	$5.42	$6.42	$7.42	$8.42	$9.42	$10.42
7 by 7	889	6.78	7.78	8.78	9.78	10.78	11.78
6 by 7	1,038	7.75	8.75	9.75	10.75	11.75	12.75
6 by 6	1,210	8.87	9.87	10.87	11.87	12.87	13.87
5 by 5	1,743	12.31	13.31	14.31	14.31	15.31	16.31

The cost of preparation varies from $1 to $3, depending on the care with which it is done and the cost of labor and animals; plowing of wide-spaced furrows without subsequent cultivation can be done for $1 an acre or less.

Two cultivations a season for two seasons will cost 50 cents to $1 per cultivation, or $2 to $4 for the two seasons. All cultivations should be given before the 1st of June, as ash does practically all its growing before the middle of June or the 1st of July. Where the stand is to be cultivated, wider spacing can be used (6 by 6 to 8 by 8) on sites where the dryness of the soil might require closer spacing if not cultivated, a saving in plants and cost of setting which would much more than pay for the costs of cultivation. On the heavy soils of the treeless and hardwood regions cultivation is almost a necessity to keep down grass and conserve moisture.

PLANTING WITH FIELD CROPS.

This is the best of all methods of establishing ash plantations on fields, as it will often be possible, by growing field crops the first two seasons, to pay for the cost of establishing the stand and having it cultivated four or five times in a season. Corn will be the usual crop to grow. The field, after being plowed (preferably the fall before), should be disked and marked off 4 by 4 in early spring, and ash seedlings planted in alternate rows spaced 8 feet apart in the row, and corn planted 4 feet apart in rows with no ash and 8 feet apart in the rows which contain ash. About four cultivations a year will usually be necessary for growing corn. Instead of planting ash seedlings, seed spotting may sometimes be used on better sites in connection with field crops.

On the Indiana State Forest, a 3-year plantation of green ash on upland, in which corn was grown the first two seasons, averaged a foot higher and was in much thriftier condition for more rapid growth than a 6-year old plantation on slightly better soil but not cultivated.

DIRECT SOWING.

The comparative cheapness of direct sowing makes it sometimes advisable, instead of planting, where there are good chances of success. The seed-spot method is the one to use: (1) For dibbling in seed under the broken cover of a mature stand to be cut in a year or two, with fair soil moisture conditions; (2) for sowing on cut-over areas free from undergrowth immediately following clean cutting of the mature stand, on good moist loamy soil; and (3) for sowing on cleared land, such as pastures, which it is not possible to prepare by ploughing. A pound to two pounds of seed will easily sow an acre, allowing 5 to 10 seed per spot and a close 4 by 4-foot spacing of spots, which is advisable in direct sowing. The holes should be dug 8 to 12 inches square and 3 to 4 inches deep (with a mattock or heavy turfing hoe), the soil broken up fine and lightly tamped down, the seed put in and half an inch of fine earth sprinkled over it. If there is any sod this can be placed, grass side down, around the edge of the hole so as form a sort of trench to hold moisture. The cost of seed-spotting, including seed, should not average over $4 per 1,000 spots, which is equivalent to $10.89 per acre for 4 by 4 spacing, $6.97 for 5 by 5 spacing, $4.84 for 6 by 6 spacing, $3.56 for 7 by 7 spacing, and $2.72 for 8 by 8 spacing.

Methods to use on prepared ground are: (1) Ploughing area, broadcasting 3 to 4 pounds of seed per acre, and harrowing it in; (2) seed-spotting at 4 to 6 foot intervals in ploughed furrows 4 to 6 feet apart. The total per acre cost would be about the same in both cases, $5 to $10 per acre.

THINNINGS.

Thinnings in crowded stands should be made an important feature in the management of ash (Pl. XIII). It is an intolerant but persistent tree, developing very rapidly in height, when crowded, at expense of diameter growth, resulting in spindling trees with short narrow crowns and long slim boles (Pl. VIII, fig. 2). It is, however, very responsive to thinnings made to increase its diameter growth (Pl. XI, fig. 1).

F11240A

FIG. 1.—Dense natural reproduction of white ash in a 60-year-old white pine stand heavily thinned 3 years ago, in which there was a slight admixture of white ash seed trees. There was also abundant white pine reproduction, but this has been outgrown by the ash. In removal of the mature stand the ash reproduction should be preserved and the pines, which survive the suppression, allowed to continue as an understory till the ash becomes merchantable and is removed, when the pine will form a second crop.

F13351A

FIG. 2.—Black ash sprouts, northern Michigan, 16 feet tall, 8 years old, from stump 230 years old. Some sprouts from above and below the root-collar; the former should be cut.

REPRODUCTION OF ASH.

F13352A

FIG. 1.—Green and red ash, 8 to 20 feet, average 13 feet high; planted 5 seasons ago, spaced 5 by 5 feet; one-year seedlings used and cultivated 2 seasons. The tallest trees with stoutest twigs are red ash, which bore seed the fourth season after planting.

F13354A

FIG. 2.—Green ash 2 to 6 feet, average 3½ feet high, near those in figure 1. One-year seedlings planted with iron spud 6 seasons ago but not cultivated.

ASH PLANTATIONS IN THE INDIANA STATE FOREST.

F12817A

FIG. 1.—Before thinning, crowns were crowded.

F12813A

FIG. 2.—After thinning, crowns were free. Crowns should be at least this distance apart after thinning to secure good development of the trees left.

LOOKING UP INTO THE CROWNS OF A TWENTY-YEAR-OLD WHITE ASH STAND.

The comparative growth of trees with varying amounts of growing space is shown in Table 22, giving the growth in 10 years of different crown classes;[1] predominant, dominant, codominant, intermediate, and suppressed. By thinning it is possible to make dominant trees out of desirable codominant and intermediate ones which are being crowded by less desirable trees, especially of other species.

By thinnings it should be possible in some cases to secure the board-feet yields indicated in Table 18 from 5 to 10 years earlier, and increase accordingly the possible interest rate on the money invested, provided the thinnings can be made to pay for themselves.

Very slight crowding of ash when comparatively young will develop long, straight, clear boles. As soon as these are established it is best, in order to get the most valuable development of the stand, to thin out so that each tree which is to form a part of the final crop will have its crown practically free on all sides (Pl. XVI). It will usually be sufficient for purposes of heavy thinning if the boles are clear for 25 feet or more from the ground, or if the branches are all dead up to that height.

TABLE 22.—*Relation of crown class, age and size of trees, and size of crown, to rate of growth in diameter and volume of white ash in New York, growing in comparatively even-aged dense stands.*

TREES ON SANDY LOAM SOIL, OSWEGO COUNTY, NEW YORK.

Crown class.	Average.			Average crown.			Growth in last 10 years.		
	Age.	Diameter breast-high.	Height.	Length.	Width.	Branch-wood 2 inches or more in diameter.	In diameter.	In volume of stem-wood inside bark.	Basis.
	Years.	*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Cu. ft.*	*Inches.*	*Cu. ft.*	*Trees.*
Suppressed	32	4.1	45.1	17.2	10.6	....	1.1	1.02	8
Dominant	41	11.3	67.1	28.1	19.8	2.16	3.2	10.00	31
Codominant	41	9.2	65.9	23.8	16.3	.72	2.3	6.31	41
Intermediate	40	7.0	57.9	22.8	13.4	.05	1.3	2.65	16
Predominant	60	17.4	68.7	40.1	29.2	10.88	2.7	15.41	7
Dominant	60	15.7	77.9	33.7	23.2	4.72	2.7	14.76	17
Codominant	60	12.4	74.9	27.9	17.7	1.57	1.8	7.94	15
Intermediate	60	9.1	69.3	24.6	16.0	.77	1.3	3.98	6
Predominant	85	19.1	90.9	33.7	30.3	8.78	4.5	30.30	3

[1] Under predominant, dominant, and codominant are included all trees which go to form the upper or main crown cover: (1) predominant, trees with crowns well above those of other trees; (2) dominant, trees with well-formed crowns, receiving light on all sides; (3) codominant, trees with uneven crowns and crowded on the sides. The intermediate and suppressed classes include overtopped trees below the upper crown cover; (4) intermediate, receiving some direct sunlight on tips of crowns; (5) suppressed, with tips of crowns shaded.

TABLE 22.—*Relation of crown class, age and size of trees, and size of crown, to rate of growth in diameter and volume of white ash in New York, growing in comparatively even-aged dense stands*—Continued.

TREES ON CLAY SOIL, OTSEGO COUNTY, NEW YORK.

Crown class.	Average.			Average crown.			Growth in last 10 years.		
	Age.	Diameter breast-high.	Height.	Length.	Width.	Branchwood 2 inches or more in diameter.	In diameter.	In volume of stemwood inside bark.	Basis.
	Years.	*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Cu. ft.*	*Inches.*	*Cu. ft.*	*Trees.*
Suppressed	66	7.0	68.1	12.0	13.0	....	1.2	2.62	1
Dominant	75	13.6	83.6	29.3	20.1	2.57	2.0	9.68	7
Codominant	76	12.5	85.5	24.4	15.7	1.83	1.3	6.96	8
Intermediate	76	9.7	77.9	22.1	12.4	.54	1.0	4.09	4
Predominant	105	19.7	94.6	40.0	24.0	9.50	2.1	16.33	1
Dominant	105	15.8	89.9	28.7	18.7	4.32	1.4	9.44	10
Codominant	105	12.5	83.4	20.1	14.2	1.44	.7	3.95	8
Intermediate	104	11.6	80.3	26.5	14.5	1.50	1.0	4.38	2
Suppressed	106	9.6	78.3	30.5	13.0	.38	1.2	4.24	2

Liberal growing space for crowns is especially important for ash over 35 years old, to enable it to lay on diameter growth. In general, however, trees in stands under 35 years of age should be kept slightly crowded, being given a medium to heavy underthinning every five to ten years, preferably commencing when the stand is 15 to 20 years old. When 35 to 40 years old the stand should be heavily thinned, amounting to a partial clearance on good sites, and the crowns of the remaining trees left free on all sides.

Ash on poorer sites is more intolerant and natural thinning more rapid than on good sites; so that the better the site the more important it is to thin and the greater the yield from thinnings. Figures on the rate of growth of individual trees on sandy and clay soils in New York (see Table 7) show faster growth in diameter and volume during youth on the poorer sandy site, while the reverse would have been the case if the stand on the better clay site had been thinned. In unthinned stands of ash under 50 years of age, the board foot yield and stumpage value per acre may be actually greater on a poorer site because of more rapid natural thinning and higher average diameters, although the total yield in cubic feet, number of trees per acre and height of stand is always greater on the better sites; this emphasizes the importance of thinnings in ash stands on good sites to concentrate the diameter growth into a smaller number of trees.

Money returns from thinning ash stands are already a possibility in some parts of the country, and as the supply of ash decreases thinnings will become more and more profitable. The yield from thinnings in some cases can be expected to equal 20 per cent or more of the returns from final cuttings of mature stands.

SUMMARY OF SPECIES OF ASH FOR MANAGEMENT.

The species of ash suited for forest management on different sites and in different regions of the United States and methods of reforestation to be used are summarized in Table 23.

TABLE 23.—*Summary of species for management in different regions.*

Region and character of site.	Species to use in order of preference.	Possibility and method of natural reproduction.	Artificial reforestation.
(1) New England, Middle, and Lake States:			
Dry upland (especially south and west slopes).	Blue ash, on rich soils only; experimental.	Poor; shelterwood system; dibbling in seed.	Planting of 2-foot seedlings, spaced 4 by 4 to 6 by 6 feet; cultivation for 2 years essential; preferably mixed plantations.
Fresh to moist upland (especially north and east slopes).	White ash, and experimentally Biltmore ash.	Fair; shelterwood system; dibbling in seed.	Planting 6 by 6, or 8 by 8 if cultivated two seasons; cultivation advisable.
Bottomland with fair surface or under drainage.	White ash, red ash, black ash.	Good; clear cutting; seed dibbling.	Planting 8 by 8, or seed spots. Subsequent thinnings.
Swamp	Black ash	Fair; clear cutting; seed dibbling.	Planting of seedlings 6 by 6 feet.
(2) Central States, Southern Appalachians and Piedmont regions:			
Dry upland (especially south and west slopes).	Blue and Biltmore ashes; on rich soils only.	Poor; shelterwood system; dibbling in seed.	Planting 2-foot seedlings, 4 by 4 to 6 by 6 feet; 2 years cultivation; mixed plantations best.
Fresh to moist upland (especially north and east slopes).	White and Biltmore ashes.	Fair	Planting 6 by 6 or 8 by 8 if cultivated two seasons; cultivation advisable.
Bottomland with fair surface or underdrainage.	White and green ashes.	Good; clear cutting.	Planting, 8 by 8, or seed spots. Subsequent thinnings.
Swamp	Black, pumpkin, and green ashes.	Fair to poor; clear cutting; seed dibbling.	Planting of seedlings 6 by 6 feet.
(3) Atlantic and Gulf Coastal Plain region:			
Fair surface or subsurface drainage.	Green and pumpkin ashes.	Good; shelterwood and clear-cutting methods; seed dibbling.	Planting 6 by 6 to 8 by 8 or seed spots. Subsequent thinnings.
Swamp	Pumpkin and green ashes.	Fair to poor; clean cutting; seed dibbling.	Planting 6 by 6.
(4) Prairie and Plains States:			
Upland	Red and green ashes.	Poor	Planting 6 by 6 and cultivated two to four seasons.
Bottom land	Green and red ashes.	Fair	Planting 6 by 6 to 8 by 8 and cultivated.
(5) Pacific Coast region:			
River flats	Oregon ash	Fair; clear cutting and shelterwood systems.	Planting 6 by 6.
(6) Southwest:			
Canyons	Leatherleaf ashes (*F. velutina* and *coriacea.*)	Poor; shelterwood system.	Planting 6 by 6. Hardly to be advised.
Irrigated land	do		Planting, irrigation, and cultivation four seasons. For shade trees and windbreaks only.

APPENDIX.

TABLES.

BARK TABLE.

Table 24—Double width of bark of white, green, and black ash.

FORM TABLES.

Tables 25 and 26—White ash form tables:
- Table 25—For trees under 75 years in age.
- Table 26—For trees over 75 years in age.

Tables 27 to 29—Green ash form tables:
- Table 27—For trees under 75 years in age.
- Table 28—For trees over 75 years in age.
- Table 29—Clear and used lengths of trees of different diameters and heights.

Table 30—Black ash form table for trees over 75 years in age.

VOLUME TABLES.

[Based on Form Tables 25-30.]

Tables 31 to 37—White ash volume tables:
- Table 31—Volume in cubic feet, peeled, for trees under 75 years in age.
- Table 32—Volume in cubic feet, peeled, foı trees over 75 years in age.
- Table 33—Volume in cords, and per cent of bark, for trees under 75 years in age.
- Table 34—Volume in cords, and per cent of bark, for trees over 75 years in age.
- Table 35—Volume and per cent of branch wood.
- Table 36—Volume table in board feet for trees of varying diameters and numbers of logs under 75 years in age.
- Table 37—Volume table in board feet for trees of varying diameters and numbers of logs over 75 years in age.

Tables 38 to 43—Green ash volume tables:
- Table 38—Volume in cubic feet, peeled, for trees under 75 years in age.
- Table 39—Volume in cubic feet, peeled, for trees over 75 years in age.
- Table 40—Volume in cords, and per cent of bark, for trees under 75 years in age.
- Table 41—Volume in cords, and per cent of bark, for trees over 75 years in age.
- Table 42—Volume table in board feet for trees of varying diameters and numbers of logs under 75 years in age.
- Table 43—Volume table in board feet for trees of varying diameters and numbers of logs over 75 years in age.

Tables 44 to 46—Black ash volume tables:
- Table 44—Volume in cubic feet, peeled, for trees over 75 years in age.
- Table 45—Volume in cords, and per cent of bark, for trees over 75 years in age.
- Table 46—Volume table in board feet for trees of varying diameters and numbers of logs over 75 years in age.

YIELD TABLES.

Tables 47 to 49—Yield of planted groves of green ash in the Plains States:
- Table 47—Yield of green ash in South Dakota.
- Table 48—Yield of green ash in Nebraska.
- Table 49—Yield of green ash in the Plains region.

TABLE 24.—*Double width of bark at breastheight for trees of different diameters and species.*

Diameter breast-high.	Green ash.			White ash.			Black ash.	
	Trees under 75 years old.	Trees 75 to 149 years old.	Basis.	Trees under 75 years old.	Trees 75 to 149 years old.	Basis.	Trees 75 to 300 years old.	Basis.
Inches.	*Inches.*	*Inches.*	*Trees.*	*Inches.*	*Inches.*	*Trees.*	*Inches.*	*Trees.*
2	....	....	....	0.3	....	....	....	....
3	.4	....	....	.3	....	9	....	....
4	.5	....	....	.4	....	16	....	....
5	.6	....	5	.5	....	13	....	....
6	.7	.8	10	.6	.8	19	.5	....
7	.7	.9	18	.6	.8	19	.5	2
8	.8	.9	18	.7	.9	15	.6	4
9	.8	.9	11	.8	1.0	23	.7	6
10	.9	1.0	19	.9	1.1	20	.8	8
11	.9	1.0	24	.9	1.2	32	.8	5
12	1.0	1.0	30	1.0	1.3	29	.8	10
13	1.0	1.0	51	1.1	1.3	34	.9	16
14	1.0	1.1	67	1.2	1.4	21	1.0	4
15	1.0	1.1	45	1.2	1.5	28	1.1	9
16	1.0	1.1	52	1.3	1.6	25	1.2	12
17	1.1	1.1	48	1.4	1.7	21	1.2	4
18	1.1	1.1	47	1.5	1.8	9	1.3	7
19	1.1	1.1	40	1.6	1.9	14	1.3	5
20	1.1	1.1	42	1.6	1.9	9	1.3	3
21	1.1	1.2	41	1.7	2.0	4	1.3	8
22	1.1	1.2	42	1.8	2.1	6	1.3	2
23	1.1	1.2	32	1.9	2.2	4	1.4	2
24	1.1	1.2	30	2.0	2.3	1	1.5	1
25	1.1	1.2	23	....	2.4	2	1.5	2
26	1.1	1.3	21	....	2.5	....	1.5	1
27	....	1.3	18	....	2.6	....	1.6	2
28	....	1.3	18	....	2.6	1	1.6	1
29	....	1.3	10	....	2.7	....	1.7	1
30	....	1.4	11	....	2.8	1	1.8	1
31	....	1.4	5	....	....	....	....	....
32	....	1.4	5	....	....	....	....	....
33	....	1.5	2	....	....	....	....	....
34	....	1.5	3	....	....	....	....	....
35	....	1.5	2	....	....	....	....	....
36	....	1.5	1	....	....	....	....	....
37	....	1.6	1	....	....	....	....	....
38	....	1.6	2	....	....	....	....	....
39	....	1.6	....	....	....	....	....	....
40	....	1.7	1	....	....	....	....	....
			795			375		116

TABLE 25.—*Form or taper for WHITE ASH trees of different diameters and heights under 75 years of age, giving diameters inside bark at different heights above the ground.*

20-FOOT TREES.

Diameter breast-high.	Height above ground—feet.													Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	
	Diameter inside bark—inches.													
Inches.														*Trees.*
2	2.4	2.2	2.0	1.7	1.1	......	......	......	......	......	......	......	......	53
3	3.5	3.2	3.0	2.7	1.7	......	......	......	......	......	......	......	......	5
4	4.6	4.3	4.0	3.6	2.2	......	......	......	......	......	......	......	......	......
5	5.7	5.3	4.9	4.5	2.9	......	......	......	......	......	......	......	......	......
6	6.9	6.3	5.9	5.4	3.5	......	......	......	......	......	......	......	......	......
														58

TABLE 25.—*Form or taper for WHITE ASH trees of different diameters and heights under 75 years of age, giving diameters inside bark at different heights above the ground*—Continued.

Diameter breast-high.	Height above ground—feet.													Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	
	Diameter inside bark—inches.													
	30-FOOT TREES.													
Inches.														*Trees.*
2	2.4	2.2	2.0	1.7	1.4	.9	......	......	......	......	......	......	......	10
3	3.5	3.2	3.0	2.7	2.1	1.3	......	......	......	......	......	......	......	20
4	4.6	4.3	4.0	3.6	2.8	1.8	......	......	......	......	......	......	......	7
5	5.7	5.3	4.9	4.5	3.4	2.2	......	......	......	......	......	......	......	4
6	6.9	6.3	5.9	5.4	4.2	2.7	......	......	......	......	......	......	......	......
7	8.0	7.4	6.9	6.4	4.8	3.1	......	......	......	......	......	......	......	......
8	9.2	8.5	7.9	7.3	5.6	3.6	......	......	......	......	......	......	......	......
														41
	40-FOOT TREES.													
2	2.4	2.2	2.0	1.7	1.5	1.2	.8	......	......	......	......	......	......	......
3	3.5	3.2	3.0	2.7	2.3	1.8	1.3	......	......	......	......	......	......	22
4	4.6	4.3	4.0	3.6	3.1	2.5	1.7	......	......	......	......	......	......	33
5	5.7	5.3	4.9	4.5	3.9	3.0	2.1	......	......	......	......	......	......	26
6	6.9	6.3	5.9	5.4	4.7	3.7	2.6	......	......	......	......	......	......	12
7	8.0	7.4	6.9	6.4	5.5	4.3	3.0	......	......	......	......	......	......	2
8	9.2	8.5	7.9	7.3	6.3	4.9	3.4	......	......	......	......	......	......	4
9	10.4	9.5	8.9	8.2	7.1	5.5	3.9	......	......	......	......	......	......	1
10	11.7	10.6	9.9	9.1	7.9	6.1	4.3	......	......	......	......	......	......	
11	12.9	11.7	10.9	10.1	8.7	6.7	4.8	......	......	......	......	......	......	......
12	14.1	12.8	11.9	11.0	9.4	7.3	5.2	......	......	......	......	......	......	......
														100
	50-FOOT TREES.													
4	4.6	4.3	4.0	3.6	3.2	2.7	2.2	1.6	......	......	......	......	......	25
5	5.7	5.3	4.9	4.5	4.1	3.4	2.8	2.0	......	......	......	......	......	25
6	6.9	6.3	5.9	5.4	4.9	4.1	3.4	2.5	......	......	......	......	......	27
7	8.0	7.4	6.9	6.4	5.7	4.8	3.9	2.8	......	......	......	......	......	12
8	9.2	8.5	7.9	7.3	6.5	5.5	4.5	3.3	......	......	......	......	......	14
9	10.4	9.5	8.9	8.2	7.4	6.2	5.0	3.6	......	......	......	......	......	3
10	11.7	10.6	9.9	9.1	8.2	6.9	5.6	4.1	......	......	......	......	......	2
11	12.9	11.7	10.9	10.1	9.0	7.5	6.1	4.5	......	......	......	......	......	2
12	14.1	12.8	11.9	11.0	9.8	8.3	6.7	4.9	......	......	......	......	......	2
13	15.3	14.0	13.0	11.9	10.7	9.0	7.3	5.4	......	......	......	......	......	1
14	16.5	15.1	14.0	12.8	11.5	9.6	7.9	5.8	......	......	......	......	......	1
15	17.6	16.2	15.0	13.8	12.3	10.3	8.4	6.2	......	......	......	......	......	1
16	18.8	17.3	16.1	14.7	13.1	10.9	8.9	6.7	......	......	......	......	......	......
														115
	60-FOOT TREES.													
4	4.6	4.3	4.0	3.6	3.4	3.1	2.7	2.2	1.5	0.9	......	......	......	......
5	5.7	5.3	4.9	4.5	4.2	3.8	3.3	2.7	2.0	1.2	......	......	......	13
6	6.9	6.3	5.9	5.4	5.1	4.5	3.9	3.2	2.4	1.4	......	......	......	30
7	8.0	7.4	6.9	6.4	5.9	5.2	4.5	3.7	2.8	1.6	......	......	......	29
8	9.2	8.5	7.9	7.3	6.7	5.9	5.1	4.3	3.2	1.9	......	......	......	37
9	10.4	9.5	8.9	8.2	7.5	6.6	5.8	4.8	3.6	2.1	......	......	......	19
10	11.7	10.6	9.9	9.1	8.3	7.3	6.4	5.3	3.9	2.3	......	......	......	12
11	12.9	11.7	10.9	10.1	9.1	8.1	7.0	5.8	4.4	2.6	......	......	......	10
12	14.1	12.8	11.9	11.0	10.0	8.8	7.6	6.4	4.8	2.9	......	......	......	6
13	15.3	14.0	13.0	11.9	10.8	9.5	8.3	6.9	5.2	3.1	......	......	......	2
14	16.5	15.1	14.0	12.8	11.6	10.3	8.9	7.5	5.6	3.4	......	......	......	1
15	17.6	16.2	15.0	13.8	12.5	11.0	9.6	8.1	6.0	3.6	......	......	......	1
16	18.8	17.3	16.1	14.7	13.3	11.7	10.3	8.6	6.5	3.9	......	......	......	2
17	20.0	18.4	17.1	15.6	14.2	12.5	11.0	9.1	6.8	4.2	......	......	......	3
18	21.2	19.5	18.2	16.5	15.0	13.3	11.7	9.7	7.3	4.4	......	......	......	1
19	22.3	20.6	19.2	17.4	15.9	14.1	12.3	10.2	7.6	4.7	......	......	......	1
20	23.5	21.7	20.2	18.4	16.7	14.9	13.0	10.8	8.1	4.9	......	......	......	......
21	24.6	22.8	21.3	19.3	17.5	15.6	13.7	11.3	8.5	5.2	......	......	......	......
22	25.8	23.9	22.3	20.2	18.4	16.4	14.4	11.8	8.9	5.5	......	......	......	1
														168

TABLE 25.—*Form or taper for WHITE ASH trees of different diameters and heights under 75 years of age, giving diameters inside bark at different heights above the ground*—Continued.

70-FOOT TREES.

Diameter breast-high.	Height above ground—feet.													Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	
	Diameter inside bark—inches.													
Inches.														*Trees.*
4	4.6	4.3	4.0	3.6	3.5	3.2	2.9	2.5	2.0	1.5	......	......	......	......
5	5.7	5.3	4.9	4.5	4.3	3.9	3.5	3.1	2.5	1.9	......	......	......	2
6	6.9	6.3	5.9	5.4	5.1	4.7	4.2	3.7	3.1	2.3	......	......	......	11
7	8.0	7.4	6.9	6.4	5.9	5.4	4.9	4.3	3.5	2.7	......	......	......	14
8	9.2	8.5	7.9	7.3	6.7	6.2	5.6	4.9	4.1	3.0	......	......	......	22
9	10.4	9.5	8.9	8.2	7.5	6.8	6.3	5.5	4.6	3.4	......	......	......	26
10	11.7	10.6	9.9	9.1	8.4	7.7	7.0	6.1	5.1	3.8	......	......	......	32
11	12.9	11.7	10.9	10.1	9.2	8.4	7.6	6.7	5.5	4.2	......	......	......	27
12	14.1	12.8	11.9	11.0	10.0	9.2	8.3	7.3	6.1	4.6	......	......	......	18
13	15.3	14.0	13.0	11.9	10.9	9.9	9.0	7.9	6.6	5.0	......	......	......	12
14	16.5	15.1	14.0	12.8	11.7	10.7	9.7	8.5	7.1	5.4	......	......	......	7
15	17.6	16.2	15.0	13.8	12.6	11.3	10.3	9.1	7.7	5.8	......	......	......	6
16	18.8	17.3	16.1	14.7	13.4	12.2	11.0	9.7	8.1	6.3	......	......	......	5
17	20.0	18.4	17.1	15.6	14.2	12.9	11.7	10.3	8.7	6.6	......	......	......	3
18	21.2	19.5	18.2	16.5	15.0	13.6	12.3	10.9	9.1	7.0	......	......	......	1
19	22.3	20.6	19.2	17.4	15.9	14.3	13.0	11.5	9.6	7.3	......	......	......	1
20	23.5	21.7	20.2	18.4	16.7	15.1	13.7	12.2	10.2	7.8	......	......	......	1
21	24.6	22.8	21.3	19.3	17.6	15.7	14.4	12.7	10.6	8.2	......	......	......	1
22	25.8	23.9	22.3	20.2	18.4	16.5	15.1	13.3	11.1	8.5	......	......	......	......
														189

80-FOOT TREES.

6	6.9	6.3	5.9	5.4	5.2	4.8	4.4	4.0	3.4	2.8	2.0	......	......	1
7	8.0	7.4	6.9	6.4	6.0	5.6	5.2	4.6	4.0	3.3	2.4	......	......	......
8	9.2	8.5	7.9	7.3	6.8	6.4	5.9	5.3	4.5	3.7	2.7	......	......	3
9	10.4	9.5	8.9	8.2	7.6	7.1	6.6	5.9	5.1	4.2	3.1	......	......	8
10	11.7	10.6	9.9	9.1	8.5	7.9	7.3	6.5	5.7	4.7	3.5	......	......	16
11	12.9	11.7	10.9	10.1	9.3	8.6	8.0	7.2	6.3	5.3	3.9	......	......	14
12	14.1	12.8	11.9	11.0	10.1	9.4	8.7	7.8	6.9	5.8	4.3	......	......	16
13	15.3	14.0	13.0	11.9	11.0	10.2	9.4	8.5	7.5	6.3	4.7	......	......	12
14	16.5	15.1	14.0	12.8	11.8	10.9	10.1	9.2	8.0	6.8	5.1	......	......	12
15	17.6	16.2	15.0	13.8	12.6	11.6	10.8	9.8	8.7	7.3	5.5	......	......	6
16	18.8	17.3	16.1	14.7	13.5	12.4	11.4	10.5	9.3	7.8	5.9	......	......	5
17	20.0	18.4	17.1	15.6	14.3	13.1	12.2	11.1	9.9	8.3	6.3	......	......	3
18	21.2	19.5	18.2	16.5	15.1	13.9	12.9	11.8	10.4	8.8	6.7	......	......	3
19	22.3	20.6	19.2	17.4	16.0	14.5	13.6	12.5	11.1	9.3	7.1	......	......	3
20	23.5	21.7	20.2	18.4	16.9	15.3	14.3	13.2	11.7	9.8	7.5	......	......	2
21	24.6	22.8	21.3	19.3	17.7	16.0	14.9	13.8	12.4	10.3	7.9	......	......	3
22	25.8	23.9	22.3	20.2	18.5	16.7	15.5	14.5	12.9	10.8	8.2	......	......	......
														107

90-FOOT TREES.

8	9.2	8.5	7.9	7.3	6.8	6.4	6.0	5.5	4.9	4.2	3.3	2.3	1.4	......
9	10.4	9.5	8.9	8.2	7.6	7.2	6.8	6.2	5.5	4.8	3.8	2.7	1.7	......
10	11.7	10.6	9.9	9.1	8.5	8.0	7.5	6.9	6.2	5.4	4.3	3.1	1.9	1
11	12.9	11.7	10.9	10.1	9.3	8.7	8.2	7.5	6.8	6.0	4.9	3.5	2.2	1
12	14.1	12.8	11.9	11.0	10.2	9.6	9.1	8.3	7.6	6.6	5.4	3.9	2.5	3
13	15.3	14.0	13.0	11.9	11.0	10.3	9.8	9.0	8.2	7.3	5.9	4.3	2.8	6
14	16.5	15.1	14.0	12.8	12.0	11.2	10.5	9.8	9.0	7.9	6.5	4.9	3.2	7
15	17.6	16.2	15.0	13.8	12.7	11.9	11.2	10.4	9.6	8.5	7.0	5.3	3.5	4
16	18.8	17.3	16.1	14.7	13.6	12.7	11.9	11.1	10.3	9.2	7.6	5.7	3.9	2
17	20.0	18.4	17.1	15.6	14.5	13.4	12.6	11.8	11.0	9.8	8.1	6.2	4.2	......
18	21.2	19.7	18.2	16.5	15.3	14.2	13.3	12.5	11.7	10.4	8.6	6.7	4.6	1
19	22.3	20.6	19.2	17.4	16.1	14.8	14.0	13.2	12.3	11.0	9.2	7.2	4.9	1
20	23.5	21.7	20.2	18.4	17.0	15.7	14.7	13.9	13.0	11.5	9.7	7.6	5.3	......
21	24.6	22.8	21.3	19.3	17.7	16.3	15.3	14.5	13.7	12.2	10.4	8.2	5.8	......
22	25.8	23.9	22.3	20.2	18.6	17.1	16.1	15.3	14.5	12.9	10.9	8.6	6.1	......
														26

TABLE 26.—*Form or taper for WHITE ASH trees of different diameters and heights, 75 to 149 years in age, giving diameters inside bark at different heights above the ground.*

Diameter, breast-high.	Height above ground—feet.																	Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	
	Diameter inside bark—inches.																	
50-FOOT TREES.																		
Inches.																		*Trees.*
6	6.7	6.2	5.6	5.2	4.5	4.0	3.4	2.4	1.1									3
7	7.7	7.2	6.6	6.2	5.5	4.8	4.1	3.1	1.7									3
8	8.7	8.2	7.6	7.1	6.4	5.7	4.9	3.7	2.0									6
9	9.8	9.2	8.6	8.0	7.3	6.4	5.5	4.3	2.5									4
10	10.8	10.2	9.5	8.9	8.2	7.3	6.3	4.9	2.9									2
11	11.9	11.1	10.4	9.8	9.1	8.1	7.1	5.7	3.3									5
12	12.9	12.1	11.3	10.7	9.9	8.9	7.8	6.2	3.7									4
13	14.0	13.1	12.3	11.7	10.9	9.7	8.5	6.9	4.1									5
14	15.1	14.1	13.3	12.6	11.7	10.5	9.2	7.5	4.5									4
15	16.2	15.1	14.2	13.5	12.6	11.3	10.0	8.1	5.1									2
16	17.2	16.1	15.2	14.4	13.4	12.1	10.7	8.7	5.4									3
17	18.3	17.1	16.2	15.3	14.4	12.9	11.4	9.5	5.8									3
18	19.4	18.1	17.1	16.2	15.2	13.7	12.1	10.0	6.4									2
19	20.4	19.1	18.1	17.1	16.1	14.4	12.8	10.6	6.7									...
20	21.5	20.1	19.0	18.1	16.9	15.2	13.5	11.2	7.2									1
21	22.6	21.1	20.0	19.0	17.8	16.0	14.2	11.8	7.7									...
22	23.7	22.1	21.0	19.9	18.7	16.8	14.9	12.5	8.2									...
																		47
60-FOOT TREES.																		
6	6.7	6.2	5.6	5.2	4.7	4.4	3.8	3.0	2.1	1.1								2
7	7.7	7.2	6.6	6.2	5.7	5.1	4.5	3.7	2.7	1.4								4
8	8.7	8.2	7.6	7.1	6.5	5.9	5.2	4.3	3.1	1.7								3
9	9.8	9.2	8.6	8.0	7.4	6.7	6.0	5.0	3.7	2.1								10
10	10.8	10.2	9.5	8.9	8.2	7.5	6.6	5.6	4.2	2.3								7
11	11.9	11.1	10.4	9.8	9.1	8.3	7.5	6.3	4.7	2.7								9
12	12.9	12.1	11.3	10.7	10.0	9.1	8.1	6.9	5.2	3.0								10
13	14.0	13.1	12.3	11.7	10.9	9.9	8.9	7.6	5.6	3.4								2
14	15.1	14.1	13.3	12.6	11.7	10.7	9.5	8.2	6.2	3.7								6
15	16.2	15.1	14.2	13.5	12.6	11.4	10.2	8.8	6.7	4.0								4

16	17.2	16.1	15.2	14.4	13.5	12.3	11.0	9.5	7.3	4.4	.....	.....	.....	.....	.....	.....	.....	5
17	18.3	17.1	16.2	15.3	14.4	13.0	11.7	10.2	7.8	4.7	.....	.....	.....	.....	.....	.....	.....	1
18	19.4	18.1	17.1	16.2	15.2	13.7	12.4	10.7	8.3	5.0	.....	.....	.....	.....	.....	.....	.....	1
19	20.4	19.1	18.1	17.1	16.1	14.5	13.1	11.4	8.9	5.3	.....	.....	.....	.....	.....	.....	.....	2
20	21.5	20.1	19.0	18.1	16.9	15.3	13.7	12.0	9.4	5.7	.....	.....	.....	.....	.....	.....	.....	2
21	22.6	21.1	20.0	19.0	17.9	16.1	14.4	12.6	9.9	6.0	.....	.....	.....	.....	.....	.....	.....	.....
22	23.7	22.1	21.0	19.9	18.7	16.9	15.1	13.2	10.4	6.3	.....	.....	.....	.....	.....	.....	.....	.....
23	24.8	23.2	21.9	20.8	19.5	17.6	15.8	13.9	10.9	6.7	.....	.....	.....	.....	.....	.....	.....	.....
24	25.9	24.2	22.9	21.7	20.3	18.3	16.5	14.4	11.4	7.0	.....	.....	.....	.....	.....	.....	.....	.....
25	27.0	25.2	23.9	22.6	21.2	19.1	17.2	15.1	11.9	7.4	.....	.....	.....	.....	.....	.....	.....	.....
26	28.2	26.2	24.8	23.5	22.0	19.8	17.8	15.7	12.5	7.7	.....	.....	.....	.....	.....	.....	.....	.....
																		68

70-FOOT TREES.

6	6.7	6.2	5.6	5.2	4.9	4.6	4.1	3.5	2.8	2.0	1.2	.....	.....	.....	.....	.....	.....	.....
7	7.7	7.2	6.6	6.2	5.8	5.3	4.8	4.1	3.5	2.6	1.5	.....	.....	.....	.....	.....	.....	1
8	8.7	8.2	7.6	7.1	6.7	6.1	5.6	4.9	4.1	3.1	1.8	.....	.....	.....	.....	.....	.....	4
9	9.8	9.2	8.6	8.0	7.5	6.9	6.3	5.6	4.7	3.6	2.2	.....	.....	.....	.....	.....	.....	4
10	10.8	10.2	9.5	8.9	8.3	7.7	7.0	6.2	5.3	4.0	2.5	.....	.....	.....	.....	.....	.....	10
11	11.9	11.1	10.4	9.8	9.2	8.4	7.7	6.9	5.9	4.6	2.8	.....	.....	.....	.....	.....	.....	10
12	12.9	12.1	11.3	10.7	10.0	9.2	8.5	7.6	6.4	5.0	3.1	.....	.....	.....	.....	.....	.....	11
13	14.0	13.1	12.3	11.7	10.9	10.0	9.2	8.3	7.0	5.4	3.4	.....	.....	.....	.....	.....	.....	15
14	15.1	14.1	13.3	12.6	11.7	10.7	9.9	8.9	7.6	5.9	3.6	.....	.....	.....	.....	.....	.....	19
15	16.2	15.1	14.2	13.5	12.7	11.5	10.6	9.5	8.2	6.3	3.9	.....	.....	.....	.....	.....	.....	12
16	17.2	16.1	15.2	14.4	13.5	12.3	11.3	10.2	8.7	6.7	4.1	.....	.....	.....	.....	.....	.....	17
17	18.3	17.1	16.2	15.3	14.4	13.1	12.0	10.8	9.2	7.2	4.5	.....	.....	.....	.....	.....	.....	8
18	19.4	18.1	17.1	16.2	15.2	13.9	12.7	11.4	9.7	7.6	4.7	.....	.....	.....	.....	.....	.....	7
19	20.4	19.1	18.1	17.1	16.2	14.6	13.5	12.1	10.2	8.0	5.0	.....	.....	.....	.....	.....	.....	4
20	21.5	20.1	19.0	18.1	17.0	15.4	14.1	12.7	10.7	8.4	5.2	.....	.....	.....	.....	.....	.....	3
21	22.6	21.1	20.0	19.0	17.9	16.2	14.8	13.2	11.2	8.7	5.4	.....	.....	.....	.....	.....	.....	1
22	23.7	22.1	21.0	19.9	18.7	16.9	15.4	13.9	11.7	9.1	5.6	.....	.....	.....	.....	.....	.....	2
23	24.8	23.2	21.9	20.8	19.6	17.7	16.1	14.4	12.2	9.5	5.9	.....	.....	.....	.....	.....	.....	3
24	25.9	24.2	22.9	21.7	20.4	18.5	16.7	15.0	12.7	9.9	6.1	.....	.....	.....	.....	.....	.....	.....
25	27.0	25.2	23.9	22.6	21.2	19.2	17.4	15.5	13.1	10.2	6.4	.....	.....	.....	.....	.....	.....	.....
26	28.2	26.2	24.8	23.5	22.1	20.0	18.0	16.0	13.6	10.6	6.6	.....	.....	.....	.....	.....	.....	1
97	29.3	27.2	25.8	24.4	23.0	20.8	18.7	16.6	14.1	10.9	6.8	.....	.....	.....	.....	.....	.....	.....
28	30.5	28.2	26.8	25.4	23.7	21.4	19.2	17.0	14.6	11.3	7.0	.....	.....	.....	.....	.....	.....	1
22	31.7	29.3	27.8	26.3	24.6	22.3	19.9	17.6	15.1	11.7	7.3	.....	.....	.....	.....	.....	.....	.....
30	32.8	30.3	28.8	27.2	25.4	22.9	20.5	18.1	15.5	12.0	7.5	.....	.....	.....	.....	.....	.....	.....
																		133

TABLE 26.—*Form or taper for WHITE ASH trees of different diameters and heights, 75 to 149 years in age, giving diameters inside bark at different heights above the ground*—Continued.

80-FOOT TREES.

Diameter, breast-high.	Height above ground—feet.																	Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	
	Diameter inside bark—inches.																	
Inches.																		*Trees.*
8	8.7	8.2	7.6	7.1	6.7	6.2	5.9	5.4	4.9	4.1	3.1	1.9						
9	9.8	9.2	8.6	8.0	7.6	7.0	6.6	6.1	5.4	4.7	3.5	2.2						5
10	10.8	10.2	9.5	8.9	8.5	7.8	7.3	6.7	6.0	5.1	3.9	2.5						3
11	11.9	11.1	10.4	9.8	9.2	8.6	8.0	7.3	6.6	5.7	4.4	2.7						13
12	12.9	12.1	11.3	10.7	10.2	9.4	8.7	8.0	7.2	6.2	4.7	3.0						15
13	14.0	13.1	12.3	11.7	11.0	10.1	9.4	8.6	7.8	6.8	5.1	3.3						13
14	15.1	14.1	13.3	12.6	11.9	10.9	10.1	9.3	8.3	7.2	5.5	3.5						8
15	16.2	15.1	14.2	13.5	12.8	11.7	10.8	10.0	8.9	7.7	5.9	3.7						6
16	17.2	16.1	15.2	14.4	13.6	12.5	11.5	10.6	9.5	8.1	6.3	4.1						9
17	18.3	17.1	16.2	15.3	14.5	13.3	12.2	11.3	10.0	8.6	6.6	4.3						4
18	19.4	18.1	17.1	16.2	15.3	14.0	13.0	11.9	10.6	9.1	7.0	4.6						7
19	20.4	19.1	18.1	17.1	16.1	14.8	13.7	12.6	11.1	9.5	7.3	4.8						6
20	21.5	20.1	19.0	18.1	17.1	15.6	14.4	13.3	11.8	10.0	7.8	5.1						6
21	22.6	21.1	20.0	19.0	17.9	16.4	15.1	13.8	12.2	10.4	8.1	5.3						3
22	23.7	22.1	21.0	19.9	18.8	17.2	15.8	14.5	12.9	10.9	8.5	5.6						2
23	24.8	23.2	21.9	20.8	19.6	17.9	16.5	15.1	13.4	11.4	8.9	5.9						
24	25.9	24.2	22.9	21.7	20.5	18.7	17.2	15.7	14.0	11.9	9.2	6.1						
25	27.0	25.2	23.9	22.6	21.3	19.5	17.9	16.3	14.4	12.2	9.5	6.3						2
26	28.2	26.2	24.8	23.5	22.2	20.3	18.6	16.9	15.0	12.7	9.8	6.5						
27	29.3	27.2	25.8	24.4	23.1	21.1	19.4	17.5	15.5	13.2	10.2	6.7						
28	30.5	28.2	26.8	25.4	24.0	21.9	20.0	18.1	16.0	13.5	10.5	7.0						
29	31.7	29.3	27.8	26.3	24.8	22.6	20.7	18.6	16.5	14.0	10.9	7.2						
30	32.8	30.3	28.8	27.2	25.8	23.5	21.3	19.2	17.0	14.4	11.2	7.5						
31	34.0	31.3	29.7	28.2	26.7	24.3	22.0	19.8	17.5	14.8	11.5	7.7						
32	35.1	32.4	30.7	29.1	27.6	25.1	22.6	20.3	17.9	15.1	11.8	8.0						
33	36.3	33.4	31.7	30.0	28.5	26.0	23.3	20.8	18.3	15.5	12.3	8.2						
34	37.4	34.4	32.7	31.0	29.4	26.6	24.0	21.5	18.9	16.0	12.5	8.5						
35	38.6	35.5	33.7	31.9	30.3	27.6	24.7	22.0	19.3	16.3	12.8	8.7						
36	39.8	36.5	34.6	32.8	31.1	28.2	25.3	22.6	19.8	16.7	13.1	8.9						
																		102

90-FOOT TREES.

10	10.8	10.2	9.5	8.9	8.6	8.0	7.6	7.1	6.6	5.9	5.1	3.7	2.2					6
11	11.9	11.1	10.4	9.8	9.4	8.8	8.2	7.7	7.2	6.5	5.6	4.1	2.6					5
12	12.9	12.1	11.3	10.7	10.3	9.6	9.0	8.5	7.9	7.1	6.0	4.5	2.9					9
13	14.0	13.1	12.3	11.7	11.2	10.4	9.7	9.1	8.5	7.6	6.5	5.0	3.3					11
14	15.1	14.1	13.3	12.6	12.1	11.1	10.4	9.8	9.1	8.2	7.0	5.4	3.6					13
15	16.2	15.1	14.2	13.5	12.9	11.9	11.1	10.4	9.7	8.7	7.4	5.8	4.0					5
16	17.2	16.1	15.2	14.4	13.7	12.7	11.9	11.1	10.4	9.3	7.9	6.1	4.2					16
17	18.3	17.1	16.2	15.3	14.6	13.5	12.5	11.8	11.0	9.9	8.4	6.6	4.6					10
18	19.4	18.1	17.1	16.2	15.4	14.2	13.2	12.4	11.6	10.4	8.8	6.9	4.9					4
19	20.4	19.1	18.1	17.1	16.3	15.0	14.0	13.1	12.2	10.9	9.2	7.3	5.2					1
20	21.5	20.1	19.0	18.1	17.2	15.9	14.7	13.8	12.8	11.4	9.7	7.7	5.5					1
21	22.6	21.1	20.0	19.0	18.0	16.6	15.4	14.4	13.3	12.0	10.2	8.1	5.8					2
22	23.7	22.1	21.0	19.9	19.0	17.4	16.2	15.2	14.0	12.5	10.6	8.5	6.0					
23	24.8	23.2	21.9	20.8	19.7	18.2	17.0	15.8	14.6	13.1	11.0	8.8	6.4					2
24	25.9	24.2	22.9	21.7	20.6	19.0	17.7	16.5	15.2	13.5	11.5	9.3	6.7					1
25	27.0	25.2	23.9	22.6	21.4	19.8	18.5	17.3	15.8	14.1	12.0	9.6	7.0					1
26	28.2	26.2	24.8	23.5	22.4	20.6	19.2	17.9	16.4	14.6	12.4	9.9	7.2					
27	29.3	27.2	25.8	24.4	23.2	21.4	20.0	18.6	16.9	15.0	12.8	10.3	7.5					
28	30.5	28.2	26.8	25.4	24.1	22.2	20.7	19.2	17.5	15.5	13.3	10.7	7.7					
29	31.7	29.3	27.8	26.3	25.0	23.0	21.4	19.9	18.2	16.1	13.7	11.0	8.0					1
30	32.8	30.3	28.8	27.2	25.9	23.8	22.2	20.6	18.7	16.6	14.1	11.4	8.3					
31	34.0	31.3	29.7	28.2	26.8	24.7	22.9	21.2	19.3	17.1	14.5	11.7	8.6					1
32	35.1	32.4	30.7	29.1	27.7	25.5	23.6	21.9	19.9	17.6	15.0	12.1	8.8					
33	36.3	33.4	31.7	30.0	28.5	26.3	24.4	22.5	20.4	18.1	15.4	12.5	9.0					
34	37.4	34.4	32.7	31.0	29.6	27.2	25.1	23.2	21.1	18.6	15.8	12.8	9.2					
35	38.6	35.5	33.7	31.9	30.4	27.9	25.8	23.8	21.6	19.1	16.3	13.1	9.5					
36	39.8	36.5	34.6	32.8	31.3	28.8	26.5	24.4	22.1	19.6	16.8	13.6	9.8					
																		89

TABLE 26.—*Form or taper for WHITE ASH trees of different diameters and heights, 75 to 149 years in age, giving diameters inside bark at different heights above the ground*—Continued.

100-FOOT TREES.

Diameter, breast-high.	Height above ground—feet.																	Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	
	Diameter inside bark—inches.																	
Inches.																		*Trees.*
12	12.9	12.1	11.3	10.7	10.2	9.7	9.1	8.7	8.2	7.5	6.7	5.7	4.4	2.9	1.5	......	......	......
13	14.0	13.1	12.3	11.7	11.2	10.5	9.9	9.4	8.9	8.1	7.3	6.2	4.8	3.2	1.7	......	......	......
14	15.1	14.1	13.3	12.6	12.0	11.3	10.6	10.0	9.5	8.8	7.8	6.6	5.2	3.6	1.9	......	......	1
15	16.2	15.1	14.2	13.5	12.9	12.0	11.4	10.8	10.1	9.4	8.4	7.1	5.7	4.0	2.1	......	......	3
16	17.2	16.1	15.2	14.4	13.8	12.8	12.1	11.5	10.8	9.9	8.8	7.6	6.1	4.3	2.3	......	......	1
17	18.3	17.1	16.2	15.3	14.6	13.6	12.8	12.2	11.4	10.5	9.4	8.1	6.5	4.6	2.5	......	......	4
18	19.4	18.1	17.1	16.2	15.5	14.4	13.6	12.9	12.1	11.1	9.9	8.6	6.9	4.9	2.7	......	......	2
19	20.4	19.1	18.1	17.1	16.4	15.2	14.3	13.6	12.7	11.7	10.5	9.1	7.4	5.3	2.9	......	......	4
20	21.5	20.1	19.0	18.1	17.3	16.0	15.1	14.3	13.4	12.3	11.1	9.5	7.7	5.6	3.1	......	......	2
21	22.6	21.1	20.0	19.0	18.1	16.8	15.8	15.0	14.0	12.9	11.6	10.1	8.2	6.0	3.4	......	......	3
22	23.7	22.1	21.0	19.9	18.9	17.5	16.5	15.7	14.7	13.5	12.2	10.6	8.6	6.2	3.6	......	......	4
23	24.8	23.2	21.9	20.8	19.8	18.3	17.3	16.4	15.4	14.1	12.7	11.1	9.1	6.6	3.8	......	......	2
24	25.9	24.2	22.9	21.7	20.7	19.2	18.1	17.1	16.1	14.8	13.3	11.5	9.4	6.8	4.0	......	......	......
25	27.0	25.2	23.9	22.6	21.6	20.0	18.8	17.8	16.6	15.3	13.8	12.0	9.8	7.2	4.1	......	......	1
26	28.2	26.2	24.8	23.5	22.4	20.8	19.6	18.5	17.3	16.0	14.4	12.5	10.3	7.5	4.3	......	......	......
27	29.3	27.2	25.8	24.4	23.3	21.6	20.3	19.3	18.0	16.6	14.9	13.0	10.7	7.8	4.5	......	......	......
28	30.5	28.2	26.8	25.4	24.3	22.5	21.1	20.0	18.7	17.2	15.5	13.7	11.1	8.1	4.7	......	......	......
29	31.7	29.3	27.8	26.3	25.2	23.3	21.9	20.7	19.4	17.8	16.0	14.0	11.5	8.4	4.8	......	......	......
30	32.8	30.3	28.8	27.2	26.0	24.1	22.7	21.4	20.1	18.5	16.6	14.5	11.9	8.7	5.0	......	......	......
31	34.0	31.3	29.7	28.2	26.9	25.0	23.5	22.2	20.7	19.1	17.1	15.0	12.3	9.0	5.2	......	......	......
32	35.1	32.4	30.7	29.1	27.8	25.8	24.2	22.9	21.4	19.7	17.7	15.4	12.7	9.3	5.4	......	......	......
33	36.3	33.4	31.7	30.0	28.7	26.7	25.0	23.6	22.1	20.3	18.2	16.0	13.2	9.6	5.6	......	......	......
34	37.4	34.4	32.7	31.0	29.7	27.6	25.8	24.3	22.8	20.9	18.8	16.5	13.5	9.9	5.8	......	......	......
35	38.6	35.5	33.7	31.9	30.5	28.3	26.5	25.0	23.4	21.5	19.3	16.9	13.9	10.2	5.9	......	......	......
36	39.8	36.5	34.6	32.8	31.4	29.2	27.3	25.7	24.1	22.2	19.9	17.4	14.3	10.5	6.0	......	......	......
																		27

110-FOOT TREES.

14	15.1	14.1	13.3	12.6	12.1	11.4	10.8	10.3	9.8	9.2	8.4	7.4	6.3	5.0	3.6	2.1	......	......
15	16.2	15.1	14.2	13.5	12.9	12.2	11.6	11.1	10.5	9.8	9.0	8.0	6.8	5.4	4.0	2.3	......	......

16......	17.2	16.1	15.2	14.4	13.9	13.0	12.3	11.7	11.2	10.5	9.6	8.5	7.3	5.9	4.2	2.5	......	......
17......	18.3	17.1	16.2	15.3	14.7	13.8	13.1	12.5	11.9	11.1	10.3	9.1	7.8	6.3	4.6	2.6	......	......
18......	19.4	18.1	17.1	16.2	15.5	14.5	13.8	13.2	12.6	11.7	10.8	9.7	8.3	6.7	4.8	2.8	......	1
19......	20.4	19.1	18.1	17.1	16.4	15.4	14.6	13.9	13.3	12.4	11.5	10.3	8.9	7.1	5.2	3.0	......	3
20......	21.5	20.1	19.0	18.1	17.4	16.1	15.3	14.7	14.0	13.1	12.1	10.9	9.4	7.6	5.5	3.2	......	2
21......	22.6	21.1	20.0	19.0	18.2	16.9	16.1	15.5	14.7	13.8	12.8	11.5	9.9	8.0	5.8	3.4	......	1
22......	23.7	22.1	21.0	19.9	19.1	17.8	16.9	16.3	15.5	14.5	13.5	12.2	10.5	8.4	6.2	3.6	......	3
23......	24.8	23.2	21.9	20.8	19.9	18.5	17.7	17.0	16.2	15.2	14.1	12.8	11.0	8.9	6.5	3.8	......	......
24......	25.9	24.2	22.9	21.7	20.8	19.4	18.5	17.7	16.9	15.9	14.8	13.4	11.5	9.3	6.9	4.0	......	......
25......	27.0	25.2	23.9	22.6	21.7	20.3	19.3	18.5	17.6	16.6	15.5	14.1	12.1	9.8	7.2	4.2	......	......
26......	28.2	26.2	24.8	23.5	22.6	21.1	20.2	19.4	18.4	17.3	16.1	14.6	12.6	10.2	7.5	4.5	......	1
27......	29.3	27.2	25.8	24.4	23.4	22.0	21.0	20.2	19.2	18.1	16.8	15.2	13.2	10.7	7.9	4.7	......	1
28......	30.5	28.2	26.8	25.4	24.4	22.8	21.7	20.8	19.8	18.7	17.5	15.8	13.7	11.0	8.3	4.9	......	......
29......	31.7	29.3	27.8	26.3	25.3	23.7	22.6	21.7	20.6	19.5	18.1	16.5	14.3	11.6	8.6	5.1	......	1
30......	32.8	30.3	28.8	27.2	26.2	24.5	23.4	22.4	21.3	20.2	18.9	17.1	14.8	12.0	8.9	5.3	......	1
31......	34.0	31.3	29.7	28.2	27.1	25.4	24.3	23.2	22.1	21.0	19.5	17.7	15.3	12.5	9.2	5.4	......	1
32......	35.1	32.4	30.7	29.1	28.0	26.3	25.1	24.0	22.9	21.7	20.3	18.3	15.8	12.9	9.6	5.7	......	......
33......	36.3	33.4	31.7	30.0	28.9	27.2	25.9	24.7	23.6	22.4	20.8	18.9	16.4	13.4	9.9	5.9	......	......
34......	37.4	34.4	32.7	31.0	29.7	28.1	26.7	25.5	24.3	23.1	21.6	19.5	17.0	13.8	10.3	6.1	......	......
35......	38.6	35.5	33.7	31.9	30.6	29.0	27.6	26.3	25.1	23.9	22.3	20.2	17.6	14.3	10.7	6.3	......	1
36......	39.8	36.5	34.6	32.8	31.5	29.9	28.5	27.1	25.8	24.6	22.9	20.7	18.0	14.8	11.0	6.5	......	......
																		16

120-FOOT TREES.

16......	17.2	16.1	15.2	14.4	13.9	13.1	12.5	12.0	11.5	10.8	10.1	9.3	8.3	7.1	5.7	4.2	2.5	......
17......	18.3	17.1	16.2	15.3	14.7	13.9	13.2	12.7	12.2	11.6	10.9	9.9	8.8	7.6	6.1	4.5	2.7	......
18......	19.4	18.1	17.1	16.2	15.7	14.7	14.0	13.4	12.9	12.3	11.5	10.6	9.4	8.0	6.5	4.7	2.8	......
19......	20.4	19.1	18.1	17.1	16.6	15.5	14.8	14.2	13.7	13.1	12.4	11.3	10.0	8.5	6.8	5.0	3.1	1
20......	21.5	20.1	19.0	18.1	17.5	16.4	15.6	15.0	14.5	13.9	13.1	12.0	10.6	9.0	7.2	5.3	3.2	......
21......	22.6	21.1	20.0	19.0	18.2	17.1	16.4	15.8	15.3	14.6	13.8	12.7	11.3	9.5	7.6	5.5	3.4	......
22......	23.7	22.1	21.0	19.9	19.1	18.0	17.2	16.6	16.1	15.4	14.6	13.4	11.9	10.1	8.0	5.9	3.6	......
23......	24.8	23.2	21.9	20.8	20.0	18.8	18.0	17.5	16.9	16.1	15.4	14.2	12.5	10.6	8.4	6.2	3.8	......
24......	25.9	24.2	22.9	21.7	20.9	19.7	18.8	18.3	17.7	17.0	16.2	14.9	13.1	11.1	8.9	6.5	4.0	......
25......	27.0	25.2	23.9	22.6	21.7	20.5	19.6	19.1	18.5	17.7	17.0	15.6	13.9	11.8	9.4	6.8	4.2	1
26......	28.2	26.2	24.8	23.5	22.7	21.4	20.4	19.9	19.3	18.5	17.7	16.3	14.5	12.3	9.8	7.2	4.4	......
27......	29.3	27.2	25.8	24.4	23.5	22.1	21.3	20.7	20.1	19.3	18.5	17.1	15.2	12.9	10.3	7.6	4.6	1
28......	30.5	28.2	26.8	25.4	24.5	23.1	22.1	21.5	20.9	20.1	19.2	17.8	15.8	13.5	10.8	7.9	4.8	1
29......	31.7	29.3	27.8	26.3	25.4	24.0	23.0	22.4	21.7	20.9	20.0	18.5	16.5	14.1	11.4	8.3	5.1	1
30......	32.8	30.3	28.8	27.2	26.3	24.8	23.9	23.2	22.5	21.6	20.7	19.3	17.2	14.7	11.9	8.7	5.3	......
31......	34.0	31.3	29.7	28.2	27.2	25.8	24.9	24.2	23.4	22.5	21.5	20.1	17.9	15.3	12.4	9.1	5.6	......
32......	35.1	32.4	30.7	29.1	28.1	26.7	25.7	24.9	24.2	23.3	22.3	20.8	18.6	16.0	13.0	9.5	5.9	1
33......	36.3	33.4	31.7	30.0	29.0	27.6	26.6	25.8	25.0	24.2	23.1	21.5	19.3	16.6	13.5	9.9	6.1	......
34......	37.4	34.4	32.7	31.0	29.9	28.5	27.4	26.6	25.9	25.0	23.8	22.2	20.0	17.3	14.1	10.3	6.3	......
35......	38.6	35.5	33.7	31.9	30.8	29.4	28.4	27.5	26.7	25.8	24.6	23.0	20.7	17.9	14.7	10.8	6.6	......
36......	39.8	36.5	34.6	32.8	31.6	30.3	29.2	28.4	27.6	26.6	25.4	23.7	21.4	18.6	15.3	11.3	6.9	......
																		6

TABLE 27.—*Form or taper table for GREEN ASH trees of different diameters and heights, under 75 years in age, giving diameters inside bark at different heights above the ground.*

40-FOOT TREES.

Diameter breast-high.	Height above ground—feet.														Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	
	Diameter inside bark—inches.														
Inches.															*Trees.*
4	5.2	4.6	4.2	3.5	3.0	2.3									6
5	6.4	5.8	5.3	4.4	3.7	2.9									7
6	7.6	6.9	6.3	5.3	4.2	3.4									2
7	8.7	8.0	7.3	6.3	4.8	3.9									6
8	9.9	9.1	8.4	7.2	5.4	4.4									4
9	11.1	10.3	9.4	8.2	6.0	4.9									
10	12.3	11.4	10.4	9.1	6.5	5.5									2
															27

50-FOOT TREES.

Diameter breast-high.	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	Basis.
4	5.2	4.6	4.2	3.5	3.2	2.7	2.2								1
5	6.4	5.8	5.3	4.4	3.9	3.3	2.7								5
6	7.6	6.9	6.3	5.3	4.5	3.9	3.2								7
7	8.7	8.0	7.3	6.3	5.1	4.4	3.6								6
8	9.9	9.1	8.4	7.2	5.8	5.0	4.1								5
9	11.1	10.3	9.4	8.2	6.4	5.6	4.6								6
10	12.3	11.4	10.4	9.1	6.9	6.1	5.1								4
11	13.5	12.5	11.5	10.1	7.6	6.6	5.6								6
12	14.8	13.7	12.6	11.0	8.1	7.1	6.1								3
13	16.0	14.8	13.6	12.0	8.7	7.7	6.6								
14	17.2	15.9	14.7	13.0	9.3	8.2	7.0								
															43

60-FOOT TREES.

6	7.6	6.9	6.3	5.3	4.9	4.3	3.9	3.3	2.4	...	...	...	...	...	4
7	8.7	8.0	7.3	6.3	5.5	4.9	4.4	3.7	2.7	...	...	...	...	...	6
8	9.9	9.1	8.4	7.2	6.1	5.5	4.9	4.1	3.0	...	...	...	...	...	3
9	11.1	10.3	9.4	8.2	6.7	6.1	5.4	4.5	3.3	...	...	...	...	...	6
10	12.3	11.4	10.4	9.1	7.4	6.6	5.9	4.9	3.6	...	...	...	...	...	6
11	13.5	12.5	11.5	10.1	8.0	7.2	6.3	5.3	3.9	...	...	...	...	...	11
12	14.8	13.7	12.6	11.0	8.6	7.8	6.9	5.7	4.2	...	...	...	...	...	6
13	16.0	14.8	13.6	12.0	9.2	8.3	7.3	6.1	4.5	...	...	...	...	...	9
14	17.2	15.9	14.7	13.0	9.8	8.8	7.7	6.5	4.7	...	...	...	...	...	3
15	18.4	17.1	15.7	14.0	10.4	9.3	8.1	6.8	5.0	...	...	...	...	...	3
16	19.6	18.2	16.8	15.0	11.0	9.9	8.6	7.1	5.3	...	...	...	...	...	2
17	20.8	19.4	17.8	15.9	11.5	10.3	9.0	7.5	5.5	...	...	...	...	...	...
18	22.0	20.5	18.9	16.9	12.1	10.9	9.4	7.8	5.9	...	...	...	...	...	2
19	23.3	21.7	20.0	17.9	12.7	11.3	9.7	8.1	6.1	...	...	...	...	...	1
20	24.5	22.8	21.1	18.9	13.3	11.8	10.2	8.5	6.4	...	...	...	...	...	...
															62

70-FOOT TREES.

6	7.6	6.9	6.3	5.3	5.1	4.6	4.2	3.9	3.4	2.7	...	...	...	...	1
7	8.7	8.0	7.3	6.3	5.8	5.2	4.8	4.4	3.8	2.9	...	...	...	...	6
8	9.9	9.1	8.4	7.2	6.5	5.9	5.4	4.9	4.1	3.1	...	...	...	...	1
9	11.1	10.3	9.4	8.2	7.1	6.5	5.9	5.3	4.5	3.3	...	...	...	...	2
10	12.3	11.4	10.4	9.1	7.8	7.2	6.5	5.9	4.9	3.6	...	...	...	...	6
11	13.5	12.5	11.5	10.1	8.5	7.8	7.1	6.3	5.3	3.8	...	...	...	...	5
12	14.8	13.7	12.6	11.0	9.2	8.4	7.6	6.8	5.7	4.1	...	...	...	...	6
13	16.0	14.8	13.6	12.0	9.9	9.1	8.1	7.2	6.0	4.4	...	...	...	...	6
14	17.2	15.9	14.7	13.0	10.5	9.7	8.7	7.7	6.5	4.7	...	...	...	...	9
15	18.4	17.1	15.7	14.0	11.2	10.3	9.3	8.1	6.8	5.0	...	...	...	...	4
16	19.6	18.2	16.8	15.0	11.8	10.9	9.8	8.7	7.3	5.3	...	...	...	...	2
17	20.8	19.4	17.8	15.9	12.5	11.5	10.3	9.1	7.6	5.6	...	...	...	...	1
18	22.0	20.5	18.9	16.9	13.1	12.1	10.9	9.6	8.0	5.9	...	...	...	...	...
19	23.3	21.7	20.0	17.9	13.7	12.7	11.4	10.1	8.4	6.2	...	...	...	...	1
20	24.5	22.8	21.1	18.9	14.3	13.2	12.0	10.5	8.8	6.5	...	...	...	...	...
21	25.8	24.0	22.2	19.9	15.0	13.8	12.5	10.9	9.1	6.9	...	...	...	...	...
22	27.1	25.2	23.3	20.9	15.6	14.4	13.0	11.5	9.5	7.2	...	...	...	...	1
23	28.3	26.3	24.4	21.9	16.2	14.9	13.6	11.9	9.9	7.5	...	...	...	...	...
24	29.6	27.5	25.4	22.9	16.9	15.5	14.1	12.5	10.3	7.9	...	...	...	...	...
															51

TABLE 27.—*Form or taper table for GREEN ASH trees of different diameters and heights, under 75 years in age, giving diameters inside bark at different heights above the ground*—Continued.

80-FOOT TREES.

Diameter breast-high.	Height above ground—feet.														Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	
	Diameter inside bark—inches.														
Inches.															*Trees.*
8	9.9	9.1	8.4	7.2	6.8	6.2	5.8	5.4	4.7	3.7	2.5	1.5			
9	11.1	10.3	9.4	8.2	7.5	6.9	6.4	5.9	5.2	4.1	3.0	1.8			1
10	12.3	11.4	10.4	9.1	8.2	7.6	7.0	6.5	5.7	4.6	3.3	2.1			1
11	13.5	12.5	11.5	10.1	8.8	8.2	7.7	7.1	6.3	5.0	3.7	2.4			2
12	14.8	13.7	12.6	11.0	9.5	8.9	8.3	7.7	6.7	5.4	4.1	2.7			6
13	16.0	14.8	13.6	12.0	10.2	9.7	9.0	8.2	7.2	5.9	4.5	3.0			7
14	17.2	15.9	14.7	13.0	11.0	10.3	9.6	8.8	7.7	6.3	4.9	3.3			5
15	18.4	17.1	15.7	14.0	11.6	11.0	10.2	9.4	8.2	6.8	5.3	3.6			7
16	19.6	18.2	16.8	15.0	12.4	11.7	10.9	10.0	8.7	7.3	5.7	3.8			3
17	20.8	19.4	17.8	15.9	13.1	12.4	11.5	10.5	9.2	7.7	6.1	4.1			2
18	22.0	20.5	18.9	16.9	13.9	13.1	12.2	11.1	9.8	8.2	6.4	4.4			3
19	23.3	21.7	20.0	17.9	14.6	13.8	12.8	11.6	10.2	8.6	6.9	4.7			2
20	24.5	22.8	21.1	18.9	15.4	14.5	13.5	12.2	10.7	9.1	7.2	4.9			
21	25.8	24.0	22.2	19.9	16.2	15.1	14.1	12.8	11.2	9.5	7.6	5.1			1
22	27.1	25.2	23.3	20.9	17.0	15.8	14.7	13.3	11.7	10.0	8.0	5.5			
23	28.3	26.3	24.4	21.9	17.9	16.5	15.3	13.9	12.3	10.4	8.4	5.7			
24	29.6	27.5	25.4	22.9	18.7	17.3	15.9	14.5	12.8	10.9	8.8	6.1			
															40

90-FOOT TREES.

Diameter breast-high.	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	Basis.
10	12.3	11.4	10.4	9.1	8.3	7.9	7.5	7.0	6.4	5.6	4.4	3.2	2.1		2
11	13.5	12.5	11.5	10.1	9.0	8.5	8.1	7.7	7.0	6.2	5.0	3.7	2.4		1
12	14.8	13.7	12.6	11.0	9.8	9.3	8.8	8.3	7.6	6.7	5.5	4.1	2.7		2
13	16.0	14.8	13.6	12.0	10.6	10.0	9.5	8.9	8.2	7.3	6.0	4.6	3.0		1
14	17.2	15.9	14.7	13.0	11.3	10.8	10.2	9.6	8.8	7.8	6.5	5.0	3.3		9
15	18.4	17.1	15.7	14.0	12.1	11.5	10.9	10.2	9.4	8.3	7.0	5.5	3.6		3
16	19.6	18.2	16.8	15.0	12.9	12.3	11.6	10.9	10.0	8.9	7.5	5.9	3.9		7
17	20.8	19.4	17.8	15.9	13.7	13.0	12.3	11.5	10.6	9.4	8.0	6.3	4.2		2
18	22.0	20.5	18.9	16.9	14.6	13.8	13.0	12.2	11.3	10.0	8.5	6.7	4.6		1
19	23.3	21.7	20.0	17.9	15.3	14.6	13.7	12.9	11.8	10.5	9.0	7.1	4.8		1

20	24.5	22.8	21.1	18.9	16.2	15.3	14.5	13.6	12.5	11.0	9.5	7.5	5.1	....	1
21	25.8	24.0	22.2	19.9	17.0	16.1	15.2	14.3	13.1	11.5	9.9	7.9	5.3	....	....
22	27.1	25.2	23.3	20.9	17.9	16.9	15.9	14.9	13.7	12.1	10.3	8.3	5.6	....	....
23	28.3	26.3	24.4	21.9	18.7	17.6	16.6	15.6	14.3	12.7	10.8	8.6	5.9	....	1
24	29.6	27.5	25.4	22.9	19.7	18.4	17.4	16.4	15.0	13.2	11.3	9.0	6.1	....	1
															32
100-FOOT TREES.															
10	12.3	11.4	10.4	9.1	8.4	8.1	7.8	7.3	6.9	6.2	5.3	4.2	3.0	1.9	....
11	13.5	12.5	11.5	10.1	9.3	8.9	8.5	8.1	7.5	6.9	6.0	4.8	3.5	2.2	....
12	14.8	13.7	12.6	11.0	10.0	9.7	9.3	8.8	8.3	7.6	6.6	5.3	3.9	2.5	1
13	16.0	14.8	13.6	12.0	10.9	10.4	10.0	9.5	8.9	8.3	7.2	5.9	4.4	2.9	....
14	17.2	15.9	14.7	13.0	11.7	11.2	10.7	10.2	9.7	8.9	7.8	6.4	4.9	3.2	2
15	18.4	17.1	15.7	14.0	12.6	11.9	11.3	10.9	10.3	9.5	8.4	6.9	5.3	3.5	2
16	19.6	18.2	16.8	15.0	13.4	12.7	12.1	11.6	11.0	10.1	9.0	7.5	5.7	3.9	3
17	20.8	19.4	17.8	15.9	14.3	13.5	12.8	12.2	11.6	10.7	9.5	7.9	6.1	4.2	4
18	22.0	20.5	18.9	16.9	15.1	14.3	13.5	12.9	12.3	11.4	10.1	8.4	6.6	4.5	1
19	23.3	21.7	20.0	17.9	15.9	15.1	14.2	13.6	12.9	11.9	10.6	8.9	6.9	4.9	4
20	24.5	22.8	21.1	18.9	16.7	15.8	15.0	14.3	13.5	12.5	11.1	9.4	7.4	5.1	2
21	25.8	24.0	22.2	19.9	17.5	16.6	15.7	14.9	14.1	13.0	11.6	9.8	7.7	5.4	1
22	27.1	25.2	23.3	20.9	18.4	17.4	16.5	15.6	14.7	13.7	12.1	10.3	8.2	5.7	1
23	28.3	26.3	24.4	21.9	19.3	18.1	17.2	16.3	15.3	14.1	12.6	10.7	8.5	6.0	2
24	29.6	27.5	25.4	22.9	20.0	18.9	17.9	17.0	15.9	14.7	13.1	11.1	8.9	6.3	....
															23

TABLE 28.—*Form or taper table for GREEN ASH trees of different diameters and heights, 75 to 149 years in age, giving diameters inside bark at different heights above the ground.*

60-FOOT TREES.

Diameter breast-high.	Height above ground—feet.																	Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	
	Diameter inside bark—inches.																	
Inches.																		*Trees.*
8	9.7	8.8	8.0	7.1	6.6	6.0	5.4	4.5	3.4	2.0								2
9	10.9	10.0	9.1	8.1	7.4	6.6	6.0	5.0	3.8	2.3								1
10	12.2	11.1	10.2	9.0	8.1	7.2	6.5	5.5	4.3	2.6								1
11	13.4	12.2	11.2	10.0	8.8	7.8	7.1	6.0	4.6	2.8								1
12	14.6	13.3	12.3	11.0	9.5	8.4	7.6	6.5	5.1	3.1								
13	15.8	14.4	13.4	12.0	10.2	9.0	8.2	7.0	5.5	3.4								2
14	17.0	15.6	14.5	12.9	10.9	9.6	8.7	7.4	5.8	3.7								2
15	18.2	16.7	15.5	13.9	11.7	10.2	9.3	8.0	6.3	4.0								1
16	19.4	17.9	16.6	14.9	12.4	10.8	9.8	8.4	6.7	4.4								3
17	20.7	19.0	17.7	15.9	13.3	11.4	10.3	8.9	7.1	4.7								
18	21.9	20.2	18.8	16.9	14.0	12.0	10.8	9.4	7.5	4.9								
19	23.2	21.4	19.9	17.9	14.9	12.5	11.3	9.9	8.0	5.2								
20	24.4	22.6	21.0	18.9	15.6	13.1	11.7	10.3	8.3	5.4								
21	25.6	23.7	22.2	19.8	16.4	13.7	12.3	10.8	8.8	5.7								2
22	26.9	24.9	23.3	20.8	17.2	14.2	12.8	11.3	9.1	6.0								1
23	28.2	26.2	24.4	21.8	18.1	14.8	13.3	11.8	9.6	6.3								
24	29.5	27.4	25.5	22.8	18.8	15.3	13.7	12.3	10.0	6.6								
25	30.8	28.7	26.7	23.8	19.6	15.9	14.2	12.7	10.4	6.8								
26	32.1	30.0	27.9	24.7	20.2	16.5	14.7	13.2	10.8	7.1								1
																		17

70-FOOT TREES.

Diameter breast-high.	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	Basis.
8	9.7	8.8	8.0	7.1	6.8	6.2	5.7	5.1	4.4	3.3	2.0							2
9	10.9	10.0	9.1	8.1	7.5	6.9	6.3	5.7	4.8	3.7	2.3							9
10	12.2	11.1	10.2	9.0	8.2	7.6	7.0	6.2	5.3	4.1	2.6							2
11	13.4	12.2	11.2	10.0	9.1	8.3	7.6	6.8	5.8	4.6	2.9							3
12	14.6	13.3	12.3	11.0	9.8	8.9	8.3	7.4	6.3	5.0	3.2							3
13	15.8	14.4	13.4	12.0	10.6	9.6	8.9	8.0	6.8	5.4	3.5							1
14	17.0	15.6	14.5	12.9	11.2	10.3	9.5	8.5	7.2	5.8	3.8							4
15	18.2	16.7	15.5	13.9	12.1	11.0	10.1	9.0	7.7	6.2	4.1							5
16	19.4	17.9	16.6	14.9	13.0	11.6	10.7	9.6	8.2	6.6	4.4							5
17	20.7	19.0	17.7	15.9	13.8	12.3	11.3	10.1	8.6	7.0	4.7							3
18	21.9	20.2	18.8	16.9	14.5	12.9	11.9	10.7	9.2	7.4	5.0							6
19	23.2	21.4	19.9	17.9	15.3	13.5	12.5	11.2	9.7	7.9	5.3							4
20	24.4	22.6	21.0	18.9	16.0	14.1	13.0	11.8	10.2	8.3	5.6							5

21	25.6	23.7	22.2	19.8	16.8	14.7	13.6	12.3	10.7	8.7	6.0							3
22	26.9	24.9	23.3	20.8	17.5	15.3	14.1	12.8	11.2	9.1	6.2							
23	28.2	26.2	24.4	21.8	18.3	15.8	14.6	13.3	11.6	9.5	6.6							
24	29.5	27.4	25.5	22.8	19.0	16.3	15.1	13.8	12.1	10.0	6.9							
25	30.8	28.7	26.7	23.8	19.7	16.9	15.6	14.3	12.6	10.4	7.3							1
26	32.1	30.0	27.9	24.7	20.4	17.4	16.0	14.8	13.1	10.8	7.6							
27	33.5	31.4	29.0	25.7	21.2	18.0	16.6	15.3	13.5	11.2	8.0							
28	34.8	32.8	30.2	26.7	21.9	18.4	17.0	15.8	14.0	11.5	8.3							
29	36.2	34.1	31.4	27.7	22.7	19.0	17.5	16.3	14.5	12.0	8.7							
30	37 7	35.5	32.6	28.6	23.4	19.5	18.0	16.8	14.9	12.4	9.0							1
31	39.2	36.9	33.7	29.6	24.3	20.1	18.5	17.4	15.4	12.8	9.5							
32	40.8	38.3	35.0	30.6	25.0	20.8	19.0	17.8	15.9	13.2	9.9							
																		57

80-FOOT TREES.

8	9.7	8.8	8.0	7.1	6.8	6.3	5.9	5.4	4.8	4.1	3.4	2.3						1
9	10.9	10.0	9.1	8.1	7.7	7.1	6.7	6.2	5.5	4.7	3.8	2.5						2
10	12.2	11.1	10.2	9.0	8.4	7.8	7.4	6.8	6.0	5.2	4.2	2.8						4
11	13.4	12.2	11.2	10.0	9.2	8.7	8.2	7.4	6.6	5.8	4.6	3.1						5
12	14.6	13.3	12.3	11.0	10.0	9.4	8.8	8.0	7.2	6.2	5.0	3.4						11
13	15.8	14.4	13.4	12.0	10.8	10.1	9.6	8.7	7.8	6.8	5.5	3.7						10
14	17.0	15.6	14.5	12.9	11.5	10.9	10.2	9.3	8.4	7.3	5.8	4.0						7
15	18.2	16.7	15.5	13.9	12.3	11.5	11.0	10.0	8.9	7.8	6.3	4.3						9
16	19.4	17.9	16.6	14.9	13.2	12.3	11.6	10.5	9.4	8.3	6.7	4.5						11
17	20.7	19.0	17.7	15.9	14.0	13.0	12.3	11.2	10.0	8.8	7.1	4.9						14
18	21.9	20.2	18.8	16.9	14.9	13.7	12.8	11.7	10.5	9.2	7.4	5.1						8
19	23.2	21.4	19.9	17.9	15.8	14.4	13.5	12.3	11.1	9.7	7.8	5.4						3
20	24.4	22.6	21.0	18.9	16.7	15.0	14.0	12.9	11.6	10.1	8.2	5.6						4
21	25.6	23.7	22.2	19.8	17.4	15.6	14.6	13.5	12.1	10.6	8.6	5.9						3
22	26.9	24.9	23.3	20.8	18.2	16.2	15.2	14.1	12.6	11.0	9.0	6.1						5
23	28.2	26.2	24.4	21.8	18.9	16.7	15.8	14.7	13.2	11.4	9.3	6.3						7
24	29.5	27.4	25.5	22.8	19.5	17.3	16.2	15.1	13.7	11.9	9.6	6.5						3
25	30.8	28.7	26.7	23.8	20.4	17.9	16.9	15.7	14.1	12.3	9.9	6.8						2
26	32.1	30.0	27.9	24.7	21.1	18.5	17.3	16.2	14.6	12.7	10.2	6.9						2
27	33.5	31.4	29.0	25.7	21.9	19.0	17.9	16.7	15.1	13.1	10.6	7.2						5
28	34.8	32.8	30.2	26.7	22.6	19.5	18.3	17.2	15.5	13.5	10.9	7.4						1
29	36.2	34.1	31.4	27.7	23.2	20.0	18.8	17.6	15.9	14.0	11.2	7.6						1
30	37.7	35.5	32.6	28.6	24.0	20.6	19.2	18.1	16.4	14.4	11.5	7.7						
31	39.2	36.9	33.7	29.6	24.7	21.1	19.7	18.5	16.8	14.8	11.8	7.9						1
32	40.8	38.3	35.0	30.6	25.5	21.6	20.1	19.0	17.3	15.2	12.1	8.1						
33	42.5	39.7	36.2	31.5	26.1	22.1	20.6	19.4	17.7	15.6	12.4	8.3						
34	44.4	41.2	37.5	32.5	26.8	22.5	21.0	19.8	18.2	16.0	12.7	8.4						1
35	46.3	42.7	38.8	33.5	27.4	23.0	21.4	20.3	18.6	16.4	13.0	8.6						
36	48.3	44.3	40.1	34.5	28.0	23.4	21.9	20.8	19.0	16.8	13.2	8.8						
37	50.5	45.9	41.4	35.4	28.9	24.2	22.4	21.3	19.5	17.1	13.5	9.0						1
38	52.9	47.6	42.7	36.4	29.8	24.8	22.9	21.7	19.9	17.5	13.8	9.1						1
																		122

TABLE 28.—*Form or taper table for GREEN ASH trees of different diameters and heights, 75 to 149 years in age, giving diameters inside bark at different heights above the ground*—Continued.

90-FOOT TREES.

Diameter breast-high.	Height above ground—feet.																	Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	
	Diameter inside bark—inches.																	
Inches.																		*Trees.*
8	9.7	8.8	8.0	7.1	6.9	6.5	6.1	5.6	5.2	4.7	4.1	3.2	2.2					1
9	10.9	10.0	9.1	8.1	7.8	7.3	6.9	6.4	5.9	5.3	4.6	3.7	2.5					2
10	12.2	11.1	10.2	9.0	8.5	8.1	7.7	7.2	6.6	5.9	5.1	4.1	2.9					6
11	13.4	12.2	11.2	10.0	9.4	8.9	8.5	7.9	7.2	6.5	5.6	4.5	3.1					13
12	14.6	13.3	12.3	11.0	10.1	9.7	9.2	8.6	7.9	7.1	6.1	4.9	3.3					12
13	15.8	14.4	13.4	12.0	11.0	10.5	10.0	9.3	8.5	7.6	6.7	5.3	3.7					13
14	17.0	15.6	14.5	12.9	11.7	11.2	10.7	10.0	9.2	8.3	7.1	5.7	4.0					14
15	18.2	16.7	15.5	13.9	12.7	12.0	11.4	10.6	9.8	8.7	7.6	6.1	4.2					11
16	19.4	17.9	16.6	14.9	13.6	12.7	12.1	11.4	10.5	9.3	8.0	6.5	4.4					18
17	20.7	19.0	17.7	15.9	14.5	13.4	12.8	12.0	11.0	9.9	8.5	6.9	4.8					16
18	21.9	20.2	18.8	16.9	15.3	14.2	13.4	12.6	11.6	10.4	9.0	7.3	5.0					16
19	23.2	21.4	19.9	17.9	16.1	14.8	14.1	13.2	12.2	10.9	9.4	7.6	5.2					17
20	24.4	22.6	21.0	18.9	16.8	15.5	14.7	13.8	12.7	11.4	9.8	7.9	5.5					13
21	25.6	23.7	22.2	19.8	17.7	16.2	15.4	14.4	13.2	11.9	10.3	8.3	5.7					16
22	26.9	24.9	23.3	20.8	18.6	16.9	15.9	15.0	13.8	12.3	10.6	8.6	5.9					11
23	28.2	26.2	24.4	21.8	19.5	17.5	16.5	15.5	14.3	12.8	11.0	8.9	6.2					6
24	29.5	27.4	25.5	22.8	20.3	18.2	17.1	16.1	14.8	13.3	11.4	9.2	6.4					9
25	30.8	28.7	26.7	23.8	21.1	18.8	17.6	16.6	15.3	13.7	11.8	9.5	6.6					5
26	32.1	30.0	27.9	24.7	21.8	19.4	18.1	17.1	15.8	14.1	12.1	9.8	6.8					8
27	33.5	31.4	29.0	25.7	22.5	19.9	18.7	17.6	16.2	14.5	12.5	10.1	7.0					8
28	34.8	32.8	30.2	26.7	23.2	20.5	19.1	18.2	16.8	15.0	12.9	10.4	7.2					2
29	36.2	34.1	31.4	27.7	24.1	21.1	19.8	18.6	17.2	15.4	13.2	10.6	7.4					5
30	37.7	35.5	32.6	28.6	24.9	21.6	20.1	19.1	17.7	15.9	13.6	10.8	7.4					2
31	39.2	36.9	33.7	29.6	25.6	22.3	20.7	19.5	18.2	16.3	14.0	11.1	7.7					3
32	40.8	38.3	35.0	30.6	26.3	22.8	21.1	20.1	18.6	16.7	14.3	11.4	7.9					2
33	42.5	39.7	36.2	31.5	27.0	23.3	21.7	20.5	19.0	17.1	14.6	11.6	8.0					1
34	44.4	41.2	37.5	32.5	27.6	23.8	22.1	21.0	19.5	17.6	15.0	11.8	8.1					
35	46.3	42.7	38.8	33.5	28.4	24.3	22.5	21.4	19.9	18.0	15.3	12.0	8.2					
36	48.3	44.3	40.1	34.5	29.2	24.9	22.9	21.9	20.4	18.4	15.6	12.3	8.3					1
37	50.5	45.9	41.4	35.4	29.8	25.3	23.4	22.3	20.8	18.8	16.0	12.5	8.6					
38	52.9	47.6	42.7	36.4	30.3	25.8	23.8	22.7	21.3	19.2	16.3	12.8	8.8					
39	55.3	49.3	44.0	37.4	31.1	26.4	24.4	23.2	21.7	19.6	16.7	13.0	8.9					
40	57.8	51.0	45.4	38.3	31.9	27.0	24.9	23.7	22.1	20.0	17.0	13.2	8.9					
41	60.5	52.7	46.8	39.3	32.8	27.8	25.4	24.0	22.5	20.4	17.4	13.4	9.0					

42	63.4	54.5	48.2	40.3	33.8	28.6	25.9	24.3	22.9	20.9	17.6	13.6	9.2	...	...	...	...	...
43	66.6	56.3	49.6	41.2	34.6	29.3	26.5	24.8	23.3	21.2	18.0	13.8	9.2	...	...	...	...	...
44	70.1	58.1	50.9	42.2	35.6	30.0	27.0	25.2	23.7	21.6	18.3	14.0	9.4	...	...	...	...	...
																		231

100-FOOT TREES.

10	12.2	11.1	10.2	9.0	8.6	8.2	7.8	7.4	7.0	6.6	6.0	5.2	4.1	2.9	...	...	...	1
11	13.4	12.2	11.2	10.0	9.5	9.0	8.8	8.3	7.8	7.1	6.5	5.6	4.4	3.1	...	...	...	3
12	14.6	13.3	12.3	11.0	10.2	9.9	9.5	8.9	8.4	7.8	7.0	6.0	4.8	3.3	...	...	...	3
13	15.8	14.4	13.4	12.0	11.2	10.6	10.3	9.7	9.0	8.3	7.5	6.4	5.1	3.6	...	...	...	8
14	17.0	15.6	14.5	12.9	12.0	11.4	10.9	10.3	9.6	8.9	8.0	6.9	5.5	3.8	...	...	...	10
15	18.2	16.7	15.5	13.9	12.9	12.2	11.8	11.0	10.3	9.5	8.5	7.3	5.8	4.0	...	...	...	13
16	19.4	17.9	16.6	14.9	13.7	13.0	12.5	11.8	11.0	10.0	9.0	7.8	6.2	4.3	...	...	...	16
17	20.7	19.0	17.7	15.9	14.6	13.8	13.3	12.6	11.6	10.6	9.5	8.1	6.5	4.6	...	...	...	13
18	21.9	20.2	18.8	16.9	15.5	14.5	13.9	13.1	12.1	11.1	10.0	8.6	6.8	4.8	...	...	...	18
19	23.2	21.4	19.9	17.9	16.4	15.2	14.6	13.7	12.8	11.7	10.5	9.0	7.2	5.1	...	...	...	25
20	24.4	22.6	21.0	18.9	17.2	16.0	15.2	14.3	13.3	12.2	10.9	9.3	7.4	5.3	...	...	...	18
21	25.6	23.7	22.2	19.8	18.1	16.7	15.9	15.0	13.9	12.7	11.4	9.7	7.8	5.5	...	...	...	13
22	26.9	24.9	23.3	20.8	18.8	17.3	16.4	15.6	14.5	13.2	11.8	10.1	8.1	5.8	...	...	...	10
23	28.2	26.2	24.4	21.8	19.7	17.9	17.1	16.2	15.1	13.7	12.2	10.5	8.4	6.0	...	...	...	15
24	29.5	27.4	25.5	22.8	20.6	18.7	17.7	16.9	15.6	14.2	12.6	10.8	8.7	6.2	...	...	...	18
25	30.8	28.7	26.7	23.8	21.4	19.3	18.2	17.3	16.1	14.6	13.0	11.2	9.1	6.4	...	...	...	10
26	32.1	30.0	27.9	24.7	22.2	20.0	18.8	17.8	16.6	15.1	13.5	11.6	9.3	6.7	...	...	...	10
27	33.5	31.4	29.0	25.7	23.0	20.6	19.4	18.3	17.0	15.6	13.9	11.9	9.6	6.9	...	...	...	7
28	34.8	32.8	30.2	26.7	23.8	21.3	20.0	18.9	17.7	16.1	14.3	12.3	9.9	7.1	...	...	...	11
29	36.2	34.1	31.4	27.7	24.7	21.9	20.5	19.5	18.1	16.6	14.7	12.6	10.2	7.3	...	...	...	4
30	37.7	35.5	32.6	28.6	25.4	22.5	21.0	20.0	18.7	17.0	15.1	13.0	10.5	7.5	...	...	...	7
31	39.2	36.9	33.7	29.6	26.2	23.0	21.5	20.5	19.2	17.5	15.5	13.3	10.7	7.7	...	...	...	7
32	40.8	38.3	35.0	30.6	27.1	23.8	22.1	21.0	19.7	17.9	15.9	13.6	10.9	7.9	...	...	...	1
33	42.5	39.7	36.2	31.5	27.8	24.2	22.6	21.5	20.2	18.4	16.3	13.9	11.2	8.0	...	...	...	2
34	44.4	41.2	37.5	32.5	28.5	24.8	23.1	22.0	20.6	18.8	16.7	14.2	11.4	8.2	...	...	...	1
35	46.3	42.7	38.8	33.5	29.5	25.4	23.6	22.5	21.1	19.3	17.1	14.6	11.8	8.3	...	...	...	2
36	48.3	44.3	40.1	34.5	30.3	26.1	24.0	23.0	21.6	19.7	17.5	14.9	12.0	8.5	...	...	...	1
37	50.5	45.9	41.4	35.4	30.9	26.6	24.6	23.4	22.0	20.2	17.9	15.2	12.3	8.7	...	...	...	1
38	52.9	47.6	42.7	36.4	31.3	27.1	25.1	24.0	22.5	20.6	18.2	15.6	12.5	8.9	...	...	...	...
39	55.3	49.3	44.0	37.4	32.2	27.7	25.6	24.4	23.0	21.1	18.6	15.8	12.7	9.0	...	...	...	...
40	57.8	51.0	45.4	38.3	32.9	28.3	26.1	25.0	23.5	21.5	19.0	16.1	12.9	9.2	...	...	...	...
41	60.5	52.7	46.8	39.3	33.8	28.8	26.6	25.5	24.0	21.9	19.4	16.4	13.1	9.3	...	...	...	...
42	63.4	54.5	48.2	40.3	34.5	29.5	27.1	26.0	24.4	22.4	19.8	16.8	13.4	9.5	...	...	...	...
43	66.6	56.3	49.6	41.2	35.2	30.0	27.7	26.4	24.9	22.8	20.2	17.0	13.5	9.6	...	...	...	...
44	70.1	58.1	50.9	42.2	35.7	30.5	28.2	27.0	25.3	23.3	20.5	17.3	13.8	9.8	...	...	...	...
																		248

TABLE 28.—*Form or taper table for GREEN ASH trees of different diameters and heights, 75 to 149 years in age, giving diameters inside bark at different heights above the ground*—Continued.

110-FOOT TREES.

Diameter breast-high.	Height above ground—feet.																	Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	
	Diameter inside bark—inches.																	
Inches.																		*Trees.*
12	14.6	13.3	12.3	11.0	10.5	10.1	9.7	9.4	8.9	8.3	7.7	6.9	6.0	4.8	3.3	1.9		
13	15.8	14.4	13.4	12.0	11.3	10.8	10.6	10.1	9.5	8.8	8.2	7.4	6.4	5.0	3.6	2.0		
14	17.0	15.6	14.5	12.9	12.1	11.6	11.3	10.7	10.1	9.4	8.7	7.7	6.7	5.4	3.8	2.2		2
15	18.2	16.7	15.5	13.9	13.0	12.4	12.0	11.4	10.7	10.0	9.1	8.2	7.1	5.6	4.0	2.3		8
16	19.4	17.9	16.6	14.9	13.7	13.1	12.7	12.0	11.3	10.5	9.5	8.5	7.4	5.9	4.2	2.4		1
17	20.7	19.0	17.7	15.9	14.7	13.9	13.5	12.7	11.9	11.0	10.0	8.9	7.7	6.2	4.4	2.5		7
18	21.9	20.2	18.8	16.9	15.5	14.7	14.1	13.3	12.5	11.6	10.5	9.3	8.1	6.4	4.6	2.7		10
19	23.2	21.4	19.9	17.9	16.4	15.4	14.8	14.0	13.0	12.1	11.1	9.8	8.4	6.7	4.8	2.8		16
20	24.4	22.6	21.0	18.9	17.2	16.1	15.4	14.5	13.6	12.6	11.5	10.1	8.7	7.0	5.1	2.9		9
21	25.6	23.7	22.2	19.8	18.1	16.9	16.2	15.2	14.2	13.1	12.0	10.6	9.1	7.3	5.3	3.1		9
22	26.9	24.9	23.3	20.8	18.8	17.6	16.8	15.8	14.7	13.6	12.4	11.0	9.4	7.5	5.5	3.2		16
23	28.2	26.2	24.4	21.8	19.8	18.3	17.4	16.4	15.3	14.1	12.9	11.5	9.8	7.8	5.7	3.4		12
24	29.5	27.4	25.5	22.8	20.6	19.0	18.0	16.9	15.8	14.6	13.4	11.8	10.1	8.1	6.0	3.6		13
25	30.8	28.7	26.7	23.8	21.5	19.7	18.7	17.6	16.4	15.2	13.9	12.2	10.4	8.4	6.2	3.7		9
26	32.1	30.0	27.9	24.7	22.2	20.3	19.2	18.1	16.9	15.7	14.3	12.6	10.8	8.7	6.4	3.8		10
27	33.5	31.4	29.0	25.7	23.0	20.9	19.9	18.7	17.5	16.2	14.8	13.1	11.2	9.0	6.6	3.9		11
28	34.8	32.8	30.2	26.7	23.8	21.6	20.5	19.3	18.1	16.7	15.2	13.4	11.6	9.3	6.8	4.0		9
29	36.2	34.1	31.4	27.7	24.7	22.2	21.1	20.0	18.6	17.2	15.7	13.9	11.8	9.6	7.0	4.1		8
30	37.7	35.5	32.6	28.6	25.6	22.9	21.6	20.5	19.2	17.8	16.2	14.2	12.2	9.8	7.2	4.2		8
31	39.2	36.9	33.7	29.6	26.4	23.6	22.3	21.1	19.7	18.3	16.6	14.7	12.6	10.1	7.4	4.3		8
32	40.8	38.3	35.0	30.6	27.2	24.2	22.8	21.7	20.3	18.7	17.0	15.0	12.9	10.4	7.6	4.4		3
33	42.5	39.7	36.2	31.5	28.0	24.9	23.5	22.2	20.8	19.2	17.5	15.5	13.2	10.6	7.8	4.5		6
34	44.4	41.2	37.5	32.5	28.7	25.5	24.1	22.9	21.3	19.7	17.9	15.8	13.5	10.8	7.9	4.7		
35	46.3	42.7	38.8	33.5	29.4	26.1	24.6	23.4	21.8	20.2	18.4	16.3	13.9	11.1	8.1	4.8		
36	48.3	44.3	40.1	34.5	30.0	26.7	25.3	24.0	22.4	20.7	18.8	16.6	14.2	11.4	8.3	4.9		2
37	50.5	45.9	41.4	35.4	30.8	27.4	25.9	24.5	23.0	21.3	19.2	17.1	14.5	11.6	8.5	5.0		1
38	52.9	47.6	42.7	36.4	31.8	28.0	26.4	25.1	23.5	21.8	19.8	17.4	14.8	11.9	8.6	5.1		1
39	55.3	49.3	44.0	37.4	32.7	28.7	27.0	25.6	24.0	22.3	20.3	17.8	15.1	12.1	8.8	5.2		
40	57.8	51.0	45.4	38.3	33.5	29.4	27.6	26.2	24.6	22.8	20.7	18.2	15.5	12.3	9.0	5.3		1
41	60.5	52.7	46.8	39.3	34.3	30.0	28.1	26.7	25.1	23.3	21.2	18.6	15.8	12.6	9.2	5.4		
42	63.4	54.5	48.2	40.3	35.1	30.7	28.7	27.3	25.7	23.8	21.6	19.0	16.1	12.9	9.3	5.5		
43	66.6	56.3	49.6	41.2	35.8	31.3	29.3	27.8	26.2	24.3	22.1	19.4	16.4	13.1	9.5	5.6		
44	70.1	58.1	50.9	42.2	36.5	32.0	29.9	28.4	26.7	24.9	22.5	19.7	16.7	13.3	9.7	5.7		1
																		181

120-FOOT TREES.

14........	17.0	15.6	14.5	12.9	12.1	11.7	11.5	10.9	10.4	9.8	9.1	8.2	7.2	6.1	4.9	3.4	1.9	1
15........	18.2	16.7	15.5	13.9	13.0	12.5	12.2	11.6	11.0	10.3	9.5	8.6	7.6	6.4	5.1	3.6	2.0	....
16........	19.4	17.9	16.6	14.9	13.8	13.3	12.9	12.3	11.6	10.9	10.1	9.0	7.9	6.7	5.4	3.8	2.1	3
17........	20.7	19.0	17.7	15.9	14.7	14.0	13.6	12.9	12.1	11.4	10.5	9.5	8.2	7.0	5.7	4.0	2.3	1
18........	21.9	20.2	18.8	16.9	15.5	14.8	14.3	13.6	12.7	11.9	11.0	9.9	8.7	7.3	5.9	4.2	2.4	....
19........	23.2	21.4	19.9	17.9	16.4	15.5	15.0	14.2	13.3	12.5	11.6	10.4	9.1	7.7	6.2	4.5	2.5	3
20........	24.4	22.6	21.0	18.9	17.3	16.3	15.6	14.8	13.9	13.0	12.1	10.8	9.5	8.0	6.5	4.7	2.6	4
21........	25.6	23.7	22.2	19.8	18.1	17.0	16.3	15.4	14.5	13.6	12.6	11.3	9.9	8.4	6.8	4.9	2.7	5
22........	26.9	24.9	23.3	20.8	18.9	17.7	16.9	16.0	15.0	14.1	13.0	11.7	10.3	8.7	7.1	5.1	2.9	6
23........	28.2	26.2	24.4	21.8	19.9	18.4	17.6	16.6	15.5	14.6	13.6	12.2	10.6	9.0	7.3	5.3	3.0	5
24........	29.5	27.4	25.5	22.8	20.7	19.1	18.2	17.3	16.2	15.2	14.0	12.6	11.0	9.3	7.6	5.5	3.1	6
25........	30.8	28.7	26.7	23.8	21.5	19.8	18.9	17.9	16.8	15.8	14.6	13.0	11.4	9.6	7.8	5.7	3.2	2
26........	32.1	30.0	27.9	24.7	22.3	20.5	19.5	18.5	17.4	16.3	15.0	13.4	11.8	9.9	8.0	5.9	3.4	4
27........	33.5	31.4	29.0	25.7	23.2	21.2	20.2	19.1	17.9	16.8	15.5	13.9	12.1	10.2	8.3	6.0	3.5	1
28........	34.8	32.8	30.2	26.7	24.0	21.9	20.8	19.8	18.5	17.3	16.0	14.3	12.6	10.6	8.6	6.2	3.6	6
29........	36.2	34.1	31.4	27.7	25.0	22.7	21.5	20.4	19.1	17.9	16.5	14.8	12.9	10.9	8.8	6.4	3.7	....
30........	37.7	35.5	32.6	28.6	25.8	23.3	22.0	20.9	19.7	18.4	17.0	15.2	13.3	11.2	9.1	6.6	3.9	1
31........	39.2	36.9	33.7	29.6	26.6	24.1	22.7	21.5	20.3	18.9	17.5	15.7	13.7	11.6	9.3	6.8	4.0	1
32........	40.8	38.3	35.0	30.6	27.3	24.7	23.4	22.2	20.9	19.5	17.9	16.0	14.0	11.7	9.6	7.0	4.1	....
33........	42.5	39.7	36.2	31.5	28.1	25.5	24.0	22.8	21.5	20.0	18.4	16.5	14.3	12.1	9.8	7.2	4.2	....
34........	44.4	41.2	37.5	32.5	28.9	26.2	24.7	23.4	22.0	20.6	18.9	16.9	14.7	12.4	10.1	7.3	4.4	1
35........	46.3	42.7	38.8	33.5	29.8	26.8	25.3	24.1	22.7	21.1	19.5	17.4	15.2	12.9	10.3	7.5	4.5	....
36........	48.3	44.3	40.1	34.5	30.8	27.7	26.0	24.6	23.3	21.8	20.1	17.9	15.6	13.1	10.6	7.7	4.6	....
37........	50.5	45.9	41.4	35.4	31.5	28.4	26.7	25.3	23.9	22.3	20.6	18.4	16.0	13.4	10.8	7.9	4.7	1
38........	52.9	47.6	42.7	36.4	32.2	29.0	27.3	25.9	24.4	22.9	21.1	18.9	16.4	13.8	11.1	8.0	4.8	1
39........	55.3	49.3	44.0	37.4	33.2	29.7	27.9	26.5	25.1	23.4	21.6	19.4	16.9	14.2	11.3	8.2	5.0	....
40........	57.8	51.0	45.4	38.3	34.0	30.4	28.6	27.2	25.6	24.0	22.2	19.8	17.2	14.5	11.6	8.4	5.1	....
41........	60.5	52.7	46.8	39.3	35.0	31.2	29.2	27.8	26.2	24.6	22.7	20.3	17.6	14.8	11.8	8.6	5.2	....
42........	63.4	54.5	48.2	40.3	35.9	31.9	29.9	28.4	26.8	25.2	23.2	20.8	18.1	15.1	12.0	8.8	5.3	....
43........	66.6	56.3	49.6	41.2	36.8	32.7	30.5	29.0	27.4	25.7	23.8	21.3	18.5	15.5	12.3	9.0	5.4	....
44........	70.1	58.1	50.9	42.2	37.5	33.4	31.2	29.6	28.0	26.3	24.3	21.7	18.8	15.7	12.6	9.1	5.6	....
																		52

TABLE 28.—*Form or taper table for GREEN ASH trees of different diameters and heights, 75 to 149 years in age, giving diameters inside bark at different heights above the ground*—Continued.

130-FOOT TREES.

Diameter breast-high.	Height above ground—feet.																	Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	
	Diameter inside bark—inches.																	
Inches.																		*Trees.*
16	19.4	17.9	16.6	14.9	14.0	13.5	13.1	12.5	11.9	11.3	10.6	9.7	8.6	7.4	6.0	4.5	3.0	
17	20.7	19.0	17.7	15.9	14.8	14.2	13.8	13.2	12.5	11.7	11.0	10.0	9.0	7.8	6.3	4.7	3.2	
18	21.9	20.2	18.8	16.9	15.7	14.9	14.4	13.9	13.1	12.3	11.4	10.4	9.3	8.1	6.6	4.9	3.4	
19	23.2	21.4	19.9	17.9	16.6	15.7	15.1	14.4	13.6	12.8	11.9	10.8	9.7	8.5	6.8	5.1	3.6	1
20	24.4	22.6	21.0	18.9	17.5	16.4	15.7	15.1	14.3	13.3	12.3	11.2	10.1	8.7	7.1	5.4	3.7	
21	25.6	23.7	22.2	19.8	18.4	17.2	16.4	15.7	14.8	13.8	12.8	11.7	10.5	9.1	7.4	5.6	3.9	1
22	26.9	24.9	23.3	20.8	19.3	17.9	17.1	16.3	15.4	14.4	13.3	12.0	10.8	9.4	7.7	5.8	4.1	
23	28.2	26.2	24.4	21.8	20.1	18.6	17.7	16.9	16.0	14.9	13.8	12.5	11.2	9.8	7.9	6.1	4.3	2
24	29.5	27.4	25.5	22.8	20.9	19.4	18.5	17.6	16.6	15.4	14.3	12.9	11.5	10.1	8.3	6.3	4.4	3
25	30.8	28.7	26.7	23.8	21.8	20.0	19.1	18.2	17.2	16.0	14.8	13.4	12.0	10.5	8.6	6.6	4.6	1
26	32.1	30.0	27.9	24.7	22.5	20.8	19.8	18.8	17.8	16.6	15.2	13.8	12.4	10.8	8.9	6.8	4.8	
27	33.5	31.4	29.0	25.7	23.5	21.5	20.4	19.4	18.4	17.2	15.7	14.2	12.8	11.1	9.2	7.1	5.0	
28	34.8	32.8	30.2	26.7	24.3	22.3	21.1	20.1	19.1	17.7	16.2	14.7	13.1	11.5	9.5	7.4	5.2	
29	36.2	34.1	31.4	27.7	25.2	23.0	21.8	20.8	19.7	18.3	16.8	15.2	13.6	11.9	9.8	7.6	5.4	
30	37.7	35.5	32.6	28.6	26.0	23.8	22.5	21.5	20.4	18.9	17.3	15.7	14.0	12.2	10.1	7.8	5.6	
31	39.2	36.9	33.7	29.6	26.9	24.5	23.2	22.1	20.9	19.5	17.9	16.1	14.5	12.6	10.4	8.0	5.7	
32	40.8	38.3	35.0	30.6	27.7	25.3	23.9	22.8	21.6	20.1	18.4	16.7	14.8	12.9	10.7	8.3	5.9	1
33	42.5	39.7	36.2	31.5	28.7	26.1	24.6	23.5	22.2	20.7	19.0	17.2	15.3	13.3	11.1	8.6	6.1	
34	44.4	41.2	37.5	32.5	29.4	26.8	25.3	24.1	22.9	21.4	19.6	17.7	15.8	13.7	11.3	8.9	6.3	
35	46.3	42.7	38.8	33.5	30.3	27.6	26.0	24.8	23.5	21.9	20.2	18.3	16.3	14.1	11.7	9.1	6.6	
36	48.3	44.3	40.1	34.5	31.1	28.3	26.8	25.5	24.2	22.6	20.8	18.9	16.8	14.5	12.0	9.4	6.7	
37	50.5	45.9	41.4	35.4	32.0	29.1	27.5	26.2	24.8	23.2	21.5	19.5	17.3	15.0	12.4	9.6	6.9	
38	52.9	47.6	42.7	36.4	32.9	29.9	28.2	26.8	25.5	24.0	22.1	20.1	17.8	15.4	12.8	10.0	7.1	
39	55.3	49.3	44.0	37.4	33.8	30.7	29.0	27.6	26.1	24.5	22.7	20.6	18.3	15.8	13.2	10.2	7.3	
40	57.8	51.0	45.4	38.3	34.7	31.5	29.7	28.3	26.9	25.2	23.3	21.2	18.8	16.3	13.5	10.5	7.5	
41	60.5	52.7	46.8	39.3	35.6	32.3	30.5	29.1	27.5	25.8	23.9	21.8	19.4	16.7	13.8	10.8	7.7	
42	63.4	54.5	48.2	40.3	36.4	33.1	31.2	29.8	28.2	26.4	24.6	22.5	19.9	17.1	14.2	11.1	7.9	1
43	66.6	56.3	49.6	41.2	37.4	33.8	32.0	30.5	28.8	27.1	25.2	23.0	20.4	17.6	14.5	11.4	8.1	
44	70.1	58.1	50.9	42.2	38.2	34.6	32.7	31.2	29.5	27.7	25.8	23.6	20.9	18.0	14.9	11.7	8.3	
																		10

TABLE 29.—*Average total height, clear length, and used length, of GREEN ASH of different diameters of a large number of trees cut in South Carolina and Arkansas in 1905.*

Diameter, breast-high.	South Carolina.			Arkansas.		
	Total height.	Clear length.	Used length.	Total height.	Clear length.	Used length.
Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	15	5	....	13	6	....
2	25	8	....	22	10	....
3	35	11	....	30	14	....
4	44	14	....	38	18	....
5	51	17	....	46	22	....
6	58	20	....	54	25	....
7	63	23	....	61	29	....
8	68	26	25	68	32	35
9	73	28	28	75	35	43
10	76	30	30	81	38	47
11	79	33	33	86	40	50
12	82	34	35	90	42	52
13	85	36	38	94	43	53
14	87	37	40	96	44	54
15	89	39	42	98	45	55
16	91	40	44	100	46	56
17	92	40	45	102	47	56
18	94	41	46	104	48	56
19	95	42	47	105	48	57
20	96	42	47	106	49	57
21	97	43	48	107	49	57
22	98	43	48	109	50	57
23	99	43	48	110	50	57
24	100	44	49	111	50	57
25	101	44	49	112	51	57
26	101	44	49	113	51	57
27	102	44	49	113	51	57
28	103	44	49	114	51	57
29	104	44	50	115	52	57
30	104	45	50	116	52	57
31	105	45	50	....	....	....
32	106	45	50	....	....	....
33	106	45	50	....	....	....
34	107	45	50	....	....	....
35	108	45	50	....	....	....
36	108	45	50	....	....	....
37	109	45	50	....	....	....
38	110	45	50	....	....	....
39	110	45	50	....	....	....
40	111	45	50	....	....	....

TABLE 30.—*Form or taper table for BLACK ASH trees of different diameters and heights, 75 to 300 years in age, giving diameters inside bark at different heights above the ground.*

60-FOOT TREES.

Diameter breast-high.	Height above ground—feet.																Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	
	Diameter inside bark—inches.																
Inches.																	*Trees.*
6	7.6	6.2	5.7	5.5	5.2	4.7	4.0	3.3	2.5	......	......	......	......	......	......	......	......
7	8.9	7.3	6.7	6.5	6.0	5.5	4.7	3.9	3.0	......	......	......	......	......	......	......	2
8	10.1	8.4	7.7	7.4	6.9	6.2	5.4	4.5	3.5	......	......	......	......	......	......	......	......
9	11.4	9.5	8.7	8.3	7.8	7.0	6.2	5.2	4.0	......	......	......	......	......	......	......	......
10	12.6	10.6	9.7	9.2	8.6	7.8	6.8	5.7	4.5	......	......	......	......	......	......	......	1
11	14.0	11.7	10.7	10.1	9.5	8.6	7.6	6.4	5.0	......	......	......	......	......	......	......	......
12	15.3	12.8	11.7	11.0	10.3	9.4	8.2	6.9	5.5	......	......	......	......	......	......	......	......
13	16.7	14.0	12.8	11.9	11.2	10.2	9.0	7.6	6.0	......	......	......	......	......	......	......	......
14	18.1	15.1	13.9	12.8	12.0	10.9	9.5	8.2	6.5	......	......	......	......	......	......	......	......
15	19.6	16.3	15.0	13.7	12.9	11.7	10.3	8.8	7.0	......	......	......	......	......	......	......	......
16	21.0	17.4	16.0	14.6	13.7	12.4	11.0	9.4	7.5	......	......	......	......	......	......	......	......
17	22.6	18.6	17.1	15.6	14.6	13.2	11.7	10.1	8.0	......	......	......	......	......	......	......	......
18	24.1	19.8	18.2	16.5	15.4	13.9	12.4	10.6	8.5	......	......	......	......	......	......	......	......
																	3

70-FOOT TREES.

Diameter breast-high.	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	Basis.
6	7.6	6.2	5.7	5.5	5.2	4.7	4.3	3.8	3.1	2.2	1.2	......	......	......	......	......	......
7	8.9	7.3	6.7	6.5	6.1	5.6	5.0	4.5	3.7	2.8	1.6	......	......	......	......	......	......
8	10.1	8.4	7.7	7.4	6.9	6.4	5.8	5.1	4.3	3.2	1.9	......	......	......	......	......	4
9	11.4	9.5	8.7	8.3	7.8	7.1	6.5	5.8	5.0	3.8	2.3	......	......	......	......	......	5
10	12.6	10.6	9.7	9.2	8.7	7.9	7.2	6.5	5.6	4.3	2.6	......	......	......	......	......	5
11	14.0	11.7	10.7	10.2	9.6	8.8	8.0	7.2	6.2	4.8	3.0	......	......	......	......	......	3
12	15.3	12.8	11.7	11.1	10.4	9.6	8.7	7.9	6.9	5.4	3.4	......	......	......	......	......	7
13	16.7	14.0	12.8	12.0	11.3	10.3	9.5	8.6	7.5	6.0	3.7	......	......	......	......	......	8
14	18.1	15.1	13.9	12.9	12.2	11.3	10.3	9.3	8.2	6.6	4.1	......	......	......	......	......	2
15	19.6	16.3	15.0	13.8	13.1	12.0	11.1	10.1	8.9	7.2	4.5	......	......	......	......	......	1
16	21.0	17.4	16.0	14.7	14.0	12.9	11.9	10.8	9.6	7.8	4.9	......	......	......	......	......	1
17	22.6	18.6	17.1	15.7	14.9	13.8	12.7	11.5	10.3	8.4	5.2	......	......	......	......	......	1
18	24.1	19.8	18.2	16.6	15.7	14.6	13.5	12.3	11.0	8.9	5.5	......	......	......	......	......	......

19........	25.6	21.0	19.2	17.6	16.7	15.5	14.3	13.1	11.7	9.6	6.0	....	....	....	....	....
20........	27.2	22.2	20.3	18.6	17.6	16.4	15.2	14.0	12.5	10.2	6.3	....	....	....	....	1
21........	28.7	23.4	21.4	19.6	18.6	17.4	16.1	14.7	13.2	10.8	6.8	....	....	....	....	1
22........	30.3	24.7	22.5	20.6	19.5	18.2	16.9	15.5	13.9	11.5	7.1	....	....	....	....	....
23........	31.8	25.9	23.6	21.5	20.4	19.1	17.8	16.3	14.6	12.1	7.5	....	....	....	....	....
24........	33.4	27.2	24.6	22.5	21.3	20.0	18.6	17.1	15.3	12.6	7.8	....	....	....	....	....
																39

80-FOOT TREES.

6........	7.6	6.2	5.7	5.5	5.1	5.0	4.6	4.1	3.5	2.8	2.0	1.1	....	....	....	....
7........	8.9	7.3	6.7	6.5	6.1	5.8	5.5	4.9	4.3	3.6	2.5	1.5	....	....	....	....
8........	10.1	8.4	7.7	7.4	7.0	6.6	6.2	5.6	5.0	4.2	3.0	1.7	....	....	....	....
9........	11.4	9.5	8.7	8.4	7.9	7.4	7.0	6.4	5.8	4.9	3.6	2.1	....	....	....	1
10........	12.6	10.6	9.7	9.3	8.8	8.2	7.7	7.2	6.5	5.5	4.0	2.4	....	....	....	2
11........	14.0	11.7	10.7	10.3	9.6	9.0	8.5	7.9	7.2	6.2	4.6	2.9	....	....	....	2
12........	15.3	12.8	11.7	11.3	10.7	10.0	9.4	8.8	7.9	6.8	5.2	3.2	....	....	....	3
13........	16.7	14.0	12.8	12.1	11.5	10.7	10.0	9.4	8.5	7.4	5.7	3.6	....	....	....	8
14........	18.1	15.1	13.9	13.0	12.4	11.5	10.8	10.1	9.2	8.0	6.2	3.9	....	....	....	2
15........	19.6	16.3	15.0	14.0	13.3	12.3	11.6	10.9	9.9	8.6	6.7	4.4	....	....	....	5
16........	21.0	17.4	16.0	14.9	14.2	13.2	12.4	11.6	10.6	9.2	7.2	4.7	....	....	....	10
17........	22.6	18.6	17.1	15.9	15.1	14.0	13.1	12.3	11.3	9.9	7.8	5.1	....	....	....	....
18........	24.1	19.8	18.2	16.7	16.0	14.8	13.8	13.0	11.9	10.5	8.3	5.5	....	....	....	5
19........	25.6	21.0	19.2	17.7	17.0	15.7	14.7	13.8	12.7	11.2	8.9	5.9	....	....	....	3
20........	27.2	22.2	20.3	18.6	17.8	16.5	15.4	14.4	13.3	11.8	9.4	6.2	....	....	....	1
21........	28.7	23.4	21.4	19.6	18.6	17.2	16.2	15.2	14.0	12.5	10.1	6.7	....	....	....	....
22........	30.3	24.7	22.5	20.6	19.5	18.1	16.9	15.9	14.6	13.1	10.6	7.0	....	....	....	1
23........	31.8	25.9	23.6	21.5	20.4	19.0	17.8	16.6	15.4	13.8	11.1	7.4	....	....	....	....
24........	33.4	27.2	24.6	22.5	21.3	19.8	18.5	17.3	16.0	14.4	11.7	7.8	....	....	....	....
25........	35.0	28.4	25.7	23.3	22.2	20.5	19.2	18.1	16.7	15.1	12.3	8.3	....	....	....	....
26........	36.7	29.7	26.8	24.3	23.0	21.3	20.0	18.7	17.3	15.7	12.8	8.5	....	....	....	....
27........	38.3	31.0	27.8	25.2	23.8	22.1	20.8	19.5	18.2	16.5	13.4	9.0	....	....	....	....
28........	39.9	32.2	28.9	26.2	24.7	22.9	21.4	20.2	18.7	17.0	13.9	9.3	....	....	....	....
29........	41.6	33.5	30.0	27.1	25.6	23.6	22.2	20.9	19.5	17.7	14.4	9.7	....	....	....	....
30........	43.2	34.7	31.1	28.0	26.4	24.4	22.9	21.5	20.0	18.3	15.0	10.0	....	....	....	....
																43

TABLE 30.—*Form or taper table for BLACK ASH trees of different diameters and heights, 75 to 300 years in age, giving diameters inside bark at different heights above the ground*—Continued.

90-FOOT TREES.

Diameter breast-high.	Height above ground—feet.																Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	
	Diameter inside bark—inches.																
Inches.																	*Trees.*
12	15.3	12.8	11.7	11.4	10.9	10.2	9.7	9.3	8.6	7.6	6.4	5.0	3.3				
13	16.7	14.0	12.8	12.3	11.7	11.0	10.5	10.0	9.2	8.1	7.0	5.4	3.6				
14	18.1	15.1	13.9	13.2	12.6	11.8	11.3	10.7	9.8	8.8	7.5	5.9	3.9				
15	19.6	16.3	15.0	14.1	13.4	12.5	12.0	11.4	10.5	9.4	8.0	6.3	4.2				3
16	21.0	17.4	16.0	15.0	14.3	13.3	12.7	12.1	11.2	10.1	8.6	6.8	4.6				1
17	22.6	18.6	17.1	16.0	15.2	14.1	13.4	12.8	11.8	10.7	9.2	7.3	4.8				3
18	24.1	19.8	18.2	16.8	16.1	14.9	14.2	13.5	12.5	11.3	9.7	7.7	5.2				2
19	25.6	21.0	19.2	17.8	16.9	15.7	15.0	14.2	13.1	11.9	10.3	8.2	5.5				2
20	27.2	22.2	20.3	18.7	17.8	16.5	15.7	14.9	13.9	12.5	10.9	8.6	5.8				1
21	28.7	23.4	21.4	19.7	18.7	17.3	16.4	15.6	14.5	13.2	11.5	9.1	6.1				6
22	30.3	24.7	22.5	20.7	19.6	18.2	17.2	16.4	15.2	13.8	12.0	9.5	6.4				1
23	31.8	25.9	23.6	21.6	20.4	18.9	18.0	17.1	15.9	14.5	12.6	10.1	6.7				1
24	33.4	27.2	24.6	22.5	21.2	19.7	18.7	17.8	16.6	15.1	13.1	10.4	7.0				1
25	35.0	28.4	25.7	23.4	22.0	20.6	19.5	18.4	17.2	15.7	13.6	10.9	7.3				2
26	36.7	29.7	26.8	24.4	23.0	21.3	20.2	19.1	17.9	16.4	14.2	11.3	7.7				
27	38.3	31.0	27.8	25.3	23.8	22.1	21.0	19.8	18.5	17.0	14.8	11.8	7.9				
28	39.9	32.2	28.9	26.3	24.7	22.9	21.7	20.6	19.2	17.7	15.4	12.2	8.2				
29	41.6	33.5	30.0	27.2	25.5	23.7	22.5	21.3	20.0	18.4	15.9	12.5	8.5				1
30	43.2	34.7	31.1	28.1	26.4	24.6	23.3	22.0	20.7	19.0	16.4	13.0	8.8				
																	24

100-FOOT TREES.

Diameter breast-high.	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	Basis.
16	21.0	17.4	16.0	15.0	14.3	13.4	12.8	12.3	11.5	10.6	9.5	8.0	6.0	3.8			
17	22.6	18.6	17.1	16.0	15.2	14.2	13.6	13.0	12.1	11.1	10.1	8.6	6.6	4.3			
18	24.1	19.8	18.2	16.9	16.1	15.0	14.4	13.7	12.8	11.8	10.7	9.2	7.1	4.7			
19	25.6	21.0	19.2	17.8	16.9	15.8	15.1	14.4	13.5	12.5	11.3	9.8	7.7	5.1			
20	27.2	22.2	20.3	18.7	17.8	16.6	15.8	15.1	14.2	13.2	11.9	10.3	8.2	5.6			
21	28.7	23.4	21.4	19.7	18.6	17.4	16.6	15.8	14.8	13.8	12.5	11.0	8.8	6.0			1
22	30.3	24.7	22.5	20.7	19.5	18.2	17.3	16.5	15.5	14.4	13.1	11.5	9.2	6.4			

23........	31.8	25.9	23.6	21.6	20.3	19.0	18.1	17.3	16.1	14.9	13.6	12.0	9.8	6.8	....	....	....
24........	33.4	27.2	24.6	22.6	21.2	19.8	18.8	18.0	16.8	15.6	14.2	12.5	10.2	7.2	....	....	....
25........	35.0	28.4	25.7	23.5	22.0	20.5	19.6	18.7	17.5	16.2	14.8	13.1	10.7	7.6	....	....	....
26........	36.7	29.7	26.8	24.5	22.9	21.3	20.3	19.4	18.2	16.8	15.3	13.5	11.2	8.0	....	....	1
27........	38.3	31.0	27.8	25.4	23.6	22.0	21.1	20.1	18.9	17.5	15.8	14.0	11.6	8.4	....	....	2
28........	39.9	32.2	28.9	26.4	24.6	22.8	21.8	20.8	19.6	18.1	16.4	14.5	12.0	8.8	....	....	....
29........	41.6	33.5	30.0	27.3	25.5	23.7	22.5	21.5	20.3	18.7	17.0	14.9	12.4	9.2	....	....	....
30........	43.2	34.7	31.1	28.2	26.3	24.5	23.3	22.2	21.0	19.4	17.5	15.4	12.9	9.5	....	....	1
																	5

110-FOOT TREES.

20........	27.2	22.2	20.3	18.7	17.8	16.4	15.6	15.1	14.3	13.4	12.6	11.9	10.8	9.0	6.9	4.3	....
21........	28.7	23.4	21.4	19.7	18.8	17.4	16.6	15.9	15.0	14.1	13.2	12.5	11.3	9.5	7.2	4.5	....
22........	30.3	24.7	22.5	20.7	19.6	18.1	17.3	16.7	15.8	14.8	13.8	13.0	11.8	10.1	7.6	4.7	....
23........	31.8	25.9	23.6	21.7	20.5	19.0	18.1	17.4	16.5	15.5	14.5	13.6	12.4	10.5	8.0	4.9	1
24........	33.4	27.2	24.6	22.6	21.4	19.8	18.9	18.1	17.2	16.2	15.2	14.2	13.0	11.1	8.4	5.1	....
25........	35.0	28.4	25.7	23.6	22.2	20.6	19.7	19.0	17.9	16.7	15.8	14.8	13.6	11.6	8.8	5.4	....
26........	36.7	29.7	26.8	24.6	23.1	21.5	20.5	19.6	18.6	17.5	16.4	15.3	14.0	12.1	9.2	5.6	....
27........	38.3	31.0	27.8	25.5	24.1	22.4	21.2	20.3	19.2	18.1	16.9	15.8	14.6	12.6	9.6	5.8	....
28........	39.9	32.2	28.9	26.5	24.8	23.3	22.2	21.1	20.1	18.8	17.6	16.4	15.1	13.1	10.0	6.1	1
29........	41.6	33.5	30.0	27.4	25.7	24.1	22.9	21.8	20.7	19.4	18.1	17.0	15.7	13.7	10.5	6.4	....
30........	43.2	34.7	31.1	28.4	26.6	24.8	23.6	22.5	21.2	20.0	18.7	17.5	16.2	14.2	10.9	6.7	....
																	2

TABLE 31.—*Volume in cubic feet of stem wood, exclusive of bark, of WHITE ASH trees of different diameters and heights, under 75 years in age; and factors to multiply by to reduce to cubic feet including bark.*

Diameter breast-high.	Total height of tree—feet.								Factors to multiply by to reduce to cubic feet including bark.	Basis.
	20	30	40	50	60	70	80	90		
	Peeled volume—cubic feet.									
Inches.										*Trees.*
2	0.2	0.2	0.3							63
3	.4	.6	.8							47
4	.7	1.1	1.4	1.8	2.1	2.5			1.23	65
5	1.1	1.6	2.2	2.7	3.3	3.8			1.22	70
6	1.6	2.3	3.1	3.9	4.7	5.5	6.2		1.22	81
7		3.2	4.2	5.3	6.3	7.4	8.4		1.21	57
8		4.1	5.5	6.8	8.2	9.6	10.9	12.3	1.21	80
9		5.1	6.9	8.6	10.3	12.0	13.7	15.4	1.20	57
10			8.6	10.7	12.9	15.0	17.2	19.3	1.20	63
11			10.3	12.9	15.4	18.0	21.0	23.0	1.20	54
12			12.3	15.4	18.5	22.0	25.0	28.0	1.19	45
13				17.9	22.0	25.0	29.0	32.0	1.19	33
14				21.0	25.0	29.0	33.0	38.0	1.18	28
15				24.0	29.0	34.0	38.0	43.0	1.18	19
16				27.0	33.0	38.0	44.0	49.0	1.18	14
17					37.0	43.0	49.0	55.0	1.17	10
18					41.0	48.0	55.0	62.0	1.17	6
19					46.0	54.0	61.0	69.0	1.17	6
20					51.0	60.0	68.0	77.0	1.16	3
21					56.0	66.0	75.0	85.0	1.16	4
22					62.0	72.0	82.0	93.0	1.16	1
										806

TABLE 32.—*Volume in cubic feet of stem wood, exclusive of bark, of WHITE ASH trees of different diameters and heights, 75 to 149 years in age; and factors to multiply by to reduce to cubic feet including bark.*

Diameter breast-high.	Total height of tree—feet.								Factors to multiply by to reduce to cubic feet including bark.	Basis.
	50	60	70	80	90	100	110	120		
	Peeled volume—cubic feet.									
Inches.										*Trees.*
6	4.0	4.8	5.6						1.38	5
7	5.4	6.5	7.6						1.36	8
8	7.0	8.4	9.8	11.2					1.34	13
9	8.8	10.6	12.3	14.1					1.32	23
10	11.0	13.2	15.4	17.6	19.8				1.31	28
11	13.2	15.8	18.5	21.0	24.0				1.30	42
12	15.8	19.0	22.0	25.0	28.0	32			1.28	49
13	18.4	22.0	26.0	29.0	33.0	37			1.27	46
14	21.0	26.0	30.0	34.0	39.0	43	47		1.26	51
15	25.0	30.0	34.0	39.0	44.0	49	54		1.25	32
16	28.0	34.0	39.0	45.0	50.0	56	62	67	1.24	51
17	32.0	38.0	44.0	51.0	57.0	63	70	76	1.23	30
18	35.0	42.0	50.0	57.0	64.0	71	78	85	1.22	24
19	39.0	47.0	55.0	63.0	71.0	79	87	95	1.21	21
20	44.0	52.0	61.0	70.0	78.0	87	96	105	1.20	17
21	48.0	58.0	67.0	77.0	87.0	96	106	116	1.19	10
22	53.0	63.0	74.0	84.0	95.0	106	116	127	1.18	11
23		69.0	81.0	92.0	104.0	116	127	139	1.17	7
24		75.0	88.0	100.0	113.0	126	138	151	1.17	1
25		82.0	95.0	109.0	123.0	136	150	164	1.16	5
26		89.0	103.0	118.0	133.0	148	162	177	1.15	2
27			111.0	127.0	143.0	159	175	191	1.15	2
28			120.0	137.0	154.0	171	188	205	1.14	2
29			129.0	147.0	165.0	184	202	220	1.14	3
30			137.0	157.0	177.0	196	216	236	1.13	1
31				168.0	189.0	210	231	252	1.13	2
32				179.0	201.0	224	246	268	1.12	1
33				190.0	214.0	238	261	285		
34				202.0	227.0	252	278	303		
35				214.0	240.0	267	294	321		1
36				226.0	255.0	283	311	339		
										488

TABLE 33.—*Volume of stem in cords,*[1] *including bark, of WHITE ASH under 75 years in age, for trees of different diameters and heights, and per cent of bark in trees of different diameters.*

[Based on taper table.]

Diameter breast-high.	Total height of tree—feet.								Bark.	Basis.
	20	30	40	50	60	70	80	90		
	Volume—cords.									
Inches.									*Per cent.*	*Trees.*
4	0.009	0.014	0.017	0.022	0.026	0.031	...	...	18.6	65
5	.013	.020	.027	.033	.040	.046	0.054	...	18.3	70
6	.020	.028	.038	.048	.057	.067	.076	...	17.9	81
7	...	.039	.051	.064	.076	.090	.102	0.115	17.6	57
8	...	.050	.067	.082	.099	.116	.132	.149	17.3	80
9	...	.061	.083	.103	.124	.144	.164	.185	17.0	57
10	...	...	.103	.128	.155	.180	.206	.232	16.7	63
11	...	...	.124	.155	.185	.216	.247	.278	16.4	54
12	...	...	.146	.183	.220	.257	.293	.330	16.1	45
13	...	...	...	.213	.256	.299	.342	.384	15.8	33
14	...	...	...	.247	.295	.345	.394	.444	15.5	28
15	...	...	...	.283	.340	.396	.453	.510	15.2	19
16	...	...	...	.322	.387	.451	.516	.579	15.0	14
17	...	...	...	...	.433	.504	.577	.649	14.7	10
18	...	...	...	...	.484	.565	.646	.727	14.4	6
19	...	...	...	...	.539	.629	.720	.808	14.2	6
20	...	...	...	...	.592	.690	.789	.887	13.9	3
21	...	...	...	...	.654	.763	.872	.981	13.7	4
22	...	...	...	...	.717	.836	.956	1.075	13.5	1
										696

[1] To reduce to cubic feet, including stump, multiply the number of cords in each case by 100.

TABLE 34.—*Volume of stem in cords,*[1] *including bark, of WHITE ASH 75 to 149 years in age, for trees of different diameters and heights, and per cent of bark in trees of different diameters.*

[Based on taper table.]

Diameter breast-high.	Total height of tree—feet.								Bark.	Basis.
	50	60	70	80	90	100	110	120		
	Volume—cords.									
Inches.									*Per cent.*	*Trees.*
6	0.055	0.066	0.077	...	...	...	...	...	27.3	5
7	.073	.088	.103	0.117	...	...	...	...	26.3	8
8	.094	.113	.131	.150	...	...	...	...	25.4	13
9	.116	.140	.162	.186	0.209	...	...	...	24.5	23
10	.144	.173	.202	.231	.259	...	...	...	23.6	28
11	.172	.205	.240	.274	.309	0.343	...	...	22.8	42
12	.202	.243	.283	.324	.364	.404	...	...	22.0	49
13	.234	.281	.328	.373	.420	.467	0.514	...	21.2	46
14	.270	.324	.378	.431	.485	.539	.593	...	20.5	51
15	.308	.369	.430	.492	.554	.615	.676	0.738	19.8	32
16	.347	.417	.486	.556	.625	.694	.764	.833	19.1	51
17	.389	.466	.544	.622	.700	.777	.855	.932	18.4	30
18	.432	.518	.605	.691	.777	.864	.950	1.037	17.7	24
19	.477	.572	.668	.762	.858	.953	1.049	1.145	17.1	21
20	.523	.628	.732	.838	.942	1.046	1.151	1.255	16.5	17
21	.574	.688	.803	.917	1.033	1.147	1.261	1.377	15.9	10
22	.623	.748	.872	.997	1.121	1.246	1.371	1.495	15.3	11
23	...	.812	.947	1.082	1.217	1.353	1.488	1.623	14.8	7
24	...	.882	1.028	1.176	1.322	1.470	1.617	1.763	14.3	1
25	...	.949	1.108	1.266	1.424	1.582	1.740	1.899	13.8	5
26	...	1.019	1.188	1.358	1.527	1.697	1.868	2.037	13.3	2
27	...	...	1.281	1.465	1.648	1.831	2.014	2.196	12.9	2
28	...	...	1.366	1.562	1.757	1.952	2.147	2.342	12.5	2
29	...	...	1.465	1.675	1.883	2.093	2.303	2.511	12.1	3
30	...	...	1.554	1.775	1.998	2.219	2.441	2.663	11.7	1
31	...	...	...	1.895	2.131	2.368	2.606	2.842	11.4	2
32	...	...	...	2.004	2.253	2.504	2.755	3.005	11.0	1
										487

[1] To reduce to cubic feet, including stump, multiply the number of cords in each case by 100.

TABLE 35.—*Average amount of branch wood 2 inches and over in diameter, in second-growth WHITE ASH trees of different diameters in New York, and the per cent which it forms of the total stem volume without the branches.*

Diameter breast-high.	Volume[1] of branch-wood.	Per cent of total stem volume.	Basis.	Diameter breast-high.	Volume[1] of branch-wood.	Per cent of total stem volume.	Basis.
Inches.	*Cubic feet.*	*Per cent.*	*Trees.*	*Inches.*	*Cubic feet.*	*Per cent.*	*Trees.*
8	0.2	2	16	16	5.7	11	10
9	.5	4	11	17	7.0	12	2
10	1.0	6	20	18	8.4	13	5
11	1.5	7	18	19	10.0	14	....
12	2.1	8	21	20	11.6	14	5
13	2.8	9	15				
14	3.6	9	9				144
15	4.6	10	12				

[1] To reduce to cords divide by 100.

TABLE 36.—*Volume in board feet of WHITE ASH, under 75 years in age, for trees of different diameters and number of logs, scaled by the Scribner log rule.*

[Based on taper curves; scaled mostly in 16.3-foot logs, with a few shorter logs where necessary. Height of stump, 1 foot. Measurements taken in Vermont, New York, Michigan, Indiana, and Tennessee.]

Diameter breast-high.	Number of 16-foot logs.								Diameter inside bark of top.	Basis.
	1½	2	2½	3	3½	4	4½	5		
	Volume—board feet.									
Inches.									*Inches.*	*Trees.*
8	25	38	50	....	....	....	....	....	6	80
9	27	41	54	72	....	....	....	....	6	57
10	30	44	60	79	100	....	....	....	6	63
11	32	48	67	88	110	....	....	....	6	54
12	35	54	75	100	120	150	....	....	6	45
13	....	62	85	110	140	170	....	....	6	33
14	....	70	95	120	150	190	220	....	6	28
15	....	80	110	140	170	210	240	....	6	19
16	....	92	120	150	190	230	270	....	6	14
17	....	....	140	170	210	250	300	....	6	10
18	....	....	150	190	230	280	330	380	6	6
19	....	....	170	220	260	310	370	420	6	6
20	....	....	200	240	290	350	410	470	6	3
21	....	....	220	270	320	390	450	520	7	4
22	....	....	240	300	360	430	490	570	7	1
23	....	....	270	330	390	470	540	620	8	....
24	....	....	300	370	430	510	580	670	8	....
										423

TABLE 37.—*Volume in board feet of WHITE ASH, 75 to 149 years in age, for trees of different diameters and number of logs, scaled by the Scribner log rule.*

[Based on taper curves; scaled mostly in 16.3-foot logs, with a few shorter logs where necessary. Height of stump, 1 foot. Measurements taken in New Hampshire, Vermont, New York, Indiana, Tennessee, West Virginia, and North Carolina.]

Diameter breast-high.	Number of 16-foot logs.									Diameter inside bark of top.	Basis.
	2	2½	3	3½	4	4½	5	5½	6		
	Volume—board feet.										
Inches.										*Inches.*	*Trees.*
8	32	43	51	69						6	13
9	37	50	60	80						6	23
10	42	58	70	91						6	28
11	49	68	80	100						6	42
12	57	78	93	120	140					6	49
13	66	90	110	130	160					6	46
14	77	100	120	150	180	200	230			6	51
15	90	120	140	170	200	230	260			6	32
16	100	130	160	190	220	260	290	330	370	6	51
17	120	150	180	210	250	290	330	370	410	6	30
18	130	170	200	240	280	320	370	410	460	6	24
19	150	190	230	270	320	360	420	460	520	6	21
20	170	210	250	300	360	410	470	520	590	6	17
21	190	230	280	340	400	460	520	590	660	7	10
22	210	260	310	380	450	510	590	660	750	7	11
23		290	350	420	500	580	660	750	840	8	7
24		320	380	460	550	650	740	840	940	9	1
25		350	420	510	610	730	830	940	1,050	9	5
26		380	460	570	680	810	920	1,050	1,170	10	2
27		410	510	630	760	890	1,020	1,160	1,300	10	2
28		450	560	690	840	980	1,130	1,280	1,440	11	2
29		480	610	760	920	1,070	1,240	1,410	1,590	11	3
30		520	660	830	1,010	1,170	1,360	1,550	1,750	12	1
31			720	900	1,100	1,280	1,490	1,690	1,910	13	2
32			790	990	1,190	1,390	1,620	1,850	2,080	13	1
33			860	1,070	1,290	1,510	1,760	2,020	2,260	14	
34			930	1,160	1,400	1,640	1,910	2,200	2,470	14	
35			1,000	1,250	1,500	1,760	2,050	2,380	2,6[illegible]0	15	1
36			1,080	1,340	1,610	1,890	2,210	2,560	2,900	16	
37			1,160	1,440	1,720	2,020	2,360	2,740	3,120	16	
38			1,240	1,540	1,830	2,160	2,520	2,930	3,350	17	
39			1,320	1,650	1,950	2,310	2,690	3,130	3,620	17	
40			1,410	1,760	2,060	2,470	2,870	3,340	3,900	18	
											475

TABLE 38.—*Volume in cubic feet of stem wood, exclusive of bark, of GREEN ASH trees of different diameters and heights, under 75 years in age, and factors to multiply by to reduce to cubic feet, including bark.*

Diameter breast-high.	Total height of tree—feet.							Factors to multiply by to reduce to cubic feet, including bark.	Basis.
	40	50	60	70	80	90	100		
	Peeled volume—cubic feet.								
Inches.									*Trees.*
4	1.4	1.8						1.29	7
5	2.0	2.7						1.28	12
6	2.8	3.7	4.6	5.5				1.27	14
7	3.7	4.8	6.0	7.2				1.25	24
8	4.6	6.0	7.6	9.1	10.9			1.24	13
9	5.7	7.4	9.2	11.1	13.4			1.23	15
10	7.0	9.1	11.2	13.5	16.3	19.3	22	1.22	21
11		10.7	13.3	15.9	19.3	23.0	26	1.21	25
12		12.6	15.6	18.8	23.0	27.0	32	1.20	24
13		14.5	17.9	22.0	26.0	31.0	37	1.19	23
14		16.6	21.0	25.0	30.0	37.0	43	1.18	28
15			23.0	28.0	34.0	42.0	49	1.17	19
16			26.0	32.0	39.0	48.0	56	1.17	17
17			29.0	36.0	44.0	53.0	63	1.16	9
18			32.0	40.0	50.0	59.0	71	1.15	7
19			35.0	44.0	55.0	66.0	79	1.15	9
20			38.0	49.0	61.0	73.0	87	1.14	3
21				53.0	67.0	80.0	96	1.14	2
22				57.0	72.0	88.0	106	1.13	2
23				63.0	79.0	96.0	116	1.13	3
24				68.0	85.0	105.0	126	1.12	1
									278

TABLE 39.—*Volume in cubic feet of stem wood, exclusive of bark, of GREEN ASH trees of different diameters and heights, 75 to 149 years in age, and factors to multiply by to reduce to cubic feet, including bark.*

Diameter breast-high.	Total height of tree—feet.								Factors to multiply by to reduce to cubic feet, including bark.	Basis.
	60	70	80	90	100	110	120	130		
	Peeled volume—cubic feet.									
Inches.										*Trees.*
8	8.6	10.0	11.5	12.9	......	......	......	......	1.27	6
9	10.7	12.5	14.3	16.0	......	......	......	......	1.26	14
10	13.2	15.4	17.6	19.8	22	......	......	......	1.25	14
11	15.8	18.5	21.0	24.0	26	......	......	......	1.24	25
12	19.0	22.0	25.0	28.0	32	35	......	......	1.22	29
13	22.0	26.0	29.0	33.0	37	40	......	......	1.21	34
14	26.0	30.0	34.0	39.0	43	47	51	......	1.20	40
15	29.0	34.0	39.0	44.0	49	53	58	......	1.19	47
16	33.0	38.0	44.0	49.0	55	60	66	71	1.19	57
17	37.0	43.0	49.0	55.0	62	68	74	80	1.18	54
18	41.0	48.0	55.0	62.0	69	76	83	90	1.17	58
19	46.0	53.0	61.0	68.0	76	83	91	99	1.16	69
20	50.0	58.0	66.0	75.0	83	91	99	108	1.15	53
21	54.0	63.0	72.0	81.0	90	99	108	117	1.15	52
22	59.0	68.0	78.0	88.0	98	107	117	127	1.14	49
23	64.0	75.0	86.0	96.0	107	118	128	139	1.14	47
24	70.0	81.0	93.0	105.0	116	128	139	151	1.13	52
25	75.0	87.0	100.0	112.0	124	137	149	162	1.13	30
26	80.0	93.0	106.0	120.0	133	146	159	173	1.13	35
27	......	100.0	115.0	129.0	143	158	172	186	1.12	32
28	......	108.0	123.0	139.0	154	169	185	200	1.12	29
29	......	114.0	130.0	147.0	163	179	196	212	1.12	18
30	......	120.0	137.0	155.0	172	189	206	223	1.12	19
31	......	128.0	147.0	165.0	183	202	220	238	1.12	20
32	......	137.0	157.0	176.0	196	215	235	254	1.11	7
33	......	......	166.0	187.0	208	229	249	270	1.11	9
34	......	......	177.0	199.0	221	243	265	287	1.11	3
35	......	......	184.0	207.0	230	254	277	300	1.11	2
36	......	......	192.0	216.0	240	264	288	312	1.11	4
37	......	......	203.0	229.0	254	279	305	330	1.11	4
38	......	......	214.0	241.0	268	295	322	348	1.11	3
39	......	......	......	254.0	282	310	339	367	1.11	......
40	......	......	......	267.0	297	327	356	386	1.11	1
41	......	......	......	281.0	312	343	374	405	1.11	......
42	......	......	......	294.0	327	360	392	425	1.11	1
43	......	......	......	308.0	343	377	411	446	1.11	......
44	......	......	......	323.0	359	395	431	467	1.11	1
										918

TABLE 40.—*Volume of stem in cords,[1] including bark, of GREEN ASH, under 75 years in age, for trees of different diameters and heights, and per cent of bark in trees of different diameters.*

[Based on taper table.]

Diameter breast-high.	Total height of tree—feet. 40	50	60	70	80	90	100	Bark.	Basis.
	Volume—cords.								
Inches.								*Per cent.*	*Trees.*
4	0.018	0.024	....	....	....	....	....	22.4	7
5	.026	.035	....	....	....	....	....	21.7	12
6	.036	.047	0.058	0.070	....	....	....	21.0	14
7	.046	.060	.075	.090	....	....	....	20.2	24
8	.057	.074	.094	.113	0.135	....	....	19.4	13
9	.070	.091	.113	.137	.165	....	....	18.6	15
10	.085	.111	.137	.165	.199	0.235	0.268	17.9	21
11	....	.129	.161	.192	.234	.277	.319	17.2	25
12	....	.151	.187	.226	.274	.324	.379	16.5	24
13	....	.173	.213	.257	.311	.375	.438	15.8	23
14	....	.196	.242	.291	.354	.432	.505	15.3	28
15	....	....	.271	.332	.402	.493	.576	14.8	19
16	....	....	.304	.378	.459	.560	.655	14.3	17
17	....	....	.335	.416	.513	.618	.733	13.8	9
18	....	....	.367	.455	.570	.677	.814	13.4	7
19	....	....	.401	.507	.635	.754	.906	13.0	9
20	....	....	.432	.556	.695	.828	.994	12.6	3
21	....	....	....	.605	.758	.915	1.099	12.2	2
22	....	....	....	.647	.811	.993	1.193	11.8	2
23	....	....	....	.709	.888	1.087	1.306	11.4	3
24	....	....	....	.763	.956	1.172	1.407	11.1	1
									278

[1] To reduce to cubic feet, including stump, multiply the number of cords in each case by 100.

TABLE 41.—*Volume of stem in cords,[1] including bark, of GREEN ASH, 75 to 149 years in age, for trees of different diameters and heights, and per cent of bark in trees of different diameters.*

[Based on taper table.]

Diameter breast-high.	Total height of tree—feet. 60	70	80	90	100	110	120	130	Bark.	Basis.
	Volume—cords.									
Inches.									*Per cent.*	*Trees.*
8	0.109	0.127	0.146	0.164	....	....	....	....	21.5	6
9	.135	.158	.180	.202	0.224	....	....	....	20.7	14
10	.165	.192	.220	.248	.275	....	....	....	19.9	14
11	.196	.229	.262	.295	.327	0.360	....	....	19.1	25
12	.232	.270	.309	.346	.386	.425	....	....	18.3	29
13	.267	.312	.356	.401	.445	.490	0.535	....	17.6	34
14	.308	.360	.410	.462	.514	.565	.617	....	16.9	40
15	.347	.405	.463	.520	.578	.635	.694	0.752	16.3	47
16	.390	.455	.520	.584	.650	.715	.779	.845	15.7	57
17	.437	.509	.582	.655	.727	.800	.872	.945	15.1	54
18	.484	.565	.646	.727	.807	.888	.969	1.049	14.5	58
19	.528	.616	.704	.792	.879	.967	1.056	1.144	14.0	69
20	.572	.667	.762	.858	.952	1.048	1.143	1.239	13.4	53
21	.623	.728	.831	.935	1.040	1.143	1.247	1.351	12.9	52
22	.668	.780	.890	1.002	1.114	1.224	1.336	1.448	12.5	49
23	.732	.854	.975	1.097	1.219	1.341	1.463	1.585	12.1	47
24	.788	.919	1.050	1.182	1.313	1.444	1.575	1.706	11.7	52
25	.844	.984	1.125	1.266	1.407	1.547	1.688	1.828	11.4	30
26	.901	1.051	1.201	1.351	1.501	1.651	1.801	1.952	11.2	35
27	....	1.123	1.284	1.445	1.605	1.765	1.925	2.087	10.9	32
28	....	1.208	1.381	1.553	1.726	1.898	2.071	2.243	10.8	29
29	....	1.278	1.460	1.643	1.824	2.007	2.190	2.372	10.6	18
30	....	1.347	1.540	1.733	1.924	2.117	2.309	2.502	10.5	19
31	....	1.438	1.643	1.849	2.054	2.259	2.465	2.670	10.4	20
32	....	1.521	1.737	1.955	2.171	2.389	2.606	2.823	10.3	7

[1] To reduce to cubic feet, including stump, multiply the number of cords in each case by 100.

TABLE 41.—*Volume of stem in cords, including bark, of GREEN ASH, 75 to 149 years in age, etc.*—Continued.

Diameter breast-high.	Total height of tree—feet.								Bark.	Basis.
	60	70	80	90	100	110	120	130		
	Volume—cords.									
Inches.									*Per cent.*	*Trees.*
33	....	....	1.846	2.077	2.308	2.539	2.769	3.000	10.2	9
34	....	....	1.961	2.207	2.452	2.696	2.942	3.187	10.1	3
35	....	....	2.047	2.302	2.559	2.814	3.070	3.326	10.1	2
36	....	....	2.135	2.401	2.668	2.935	3.202	3.469	10.1	4
37	....	....	2.256	2.537	2.819	3.101	3.383	3.665	10.0	4
38	....	....	2.379	2.676	2.974	3.271	3.569	3.866	10.0	3
39	....	....	....	2.819	3.132	3.445	3.758	4.073	10.0	....
40	....	....	....	2.965	3.294	3.624	3.954	4.283	10.0	1
41	....	....	....	3.115	3.461	3.807	4.153	4.499	10.0	....
42	....	....	....	3.268	3.631	3.994	4.357	4.720	10.0	1
43	....	....	....	3.423	3.804	4.185	4.565	4.945	10.0	....
44	....	....	....	3.586	3.985	4.383	4.782	5.181	10.0	1
										918

TABLE 42.—*Volume in board feet of GREEN ASH, under 75 years in age, for trees of different diameters, and number of logs, scaled by the Scribner log rule.*

[Based on taper curves; scaled mostly in 16.3-foot logs, with a few shorter logs where necessary. Height of stump, 1 foot. Measurements taken in South Carolina and Arkansas.]

Diameter breast-high.	Number of 16-foot logs.									Diameter inside bark of top.	Basis.
	1	1½	2	2½	3	3½	4	4½	5		
	Volume—board feet.										
Inches.										*Inches.*	*Trees.*
8	15	24	36	....	....	....	....	....	....	6	13
9	16	26	38	51	....	....	....	....	....	6	16
10	17	27	41	56	75	....	....	....	....	6	21
11	18	29	44	62	82	110	....	....	....	6	25
12	20	31	47	67	90	120	150	....	....	6	24
13	22	33	50	72	100	130	160	200	....	6	23
14	23	35	54	78	110	140	180	210	250	6	28
15	....	38	58	86	120	150	190	230	270	6	19
16	....	42	63	95	130	170	210	260	300	6	17
17	....	....	69	100	140	190	230	280	330	6	9
18	....	....	75	110	160	200	250	310	360	6	7
19	....	....	....	120	170	220	280	340	410	6	9
20	....	....	....	130	180	250	310	380	460	6	3
21	....	....	....	140	200	270	350	430	510	7	2
22	....	....	....	150	220	300	390	490	580	7	2
23	....	....	....	....	240	340	440	550	650	8	3
24	....	....	....	....	260	370	490	610	730	8	1
25	....	....	....	....	280	410	550	680	810	9	1
26	....	....	....	....	300	450	600	750	900	10	....
											223

TABLE 43.—*Volume in board feet of GREEN ASH, 75 to 149 years in age, for trees of different diameters and number of logs, scaled by the Scribner log rule.*

[Based on taper curves; scaled mostly in 16.3-foot logs, with a few shorter logs where necessary. Height of stump, 1 foot. Measurements taken in South Carolina and Arkansas.]

Diameter breast-high.	Number of 16-foot logs.									Diameter inside bark of top.	Basis.
	2	2½	3	3½	4	4½	5	5½	6		
	Volume—board feet.										
Inches.										*Inches.*	*Trees.*
8	37	47	56	....	....	....	....	....	....	6	6
9	40	52	65	....	....	....	....	....	....	6	14
10	43	57	74	88	100	120	130	....	....	6	14
11	45	63	83	100	120	140	160	....	....	6	25
12	48	69	92	110	140	160	180	....	....	6	29
13	50	74	100	130	160	180	210	....	....	6	34
14	53	80	110	140	170	210	240	270	300	6	40
15	56	86	120	160	190	230	270	300	340	6	47
16	59	93	130	170	220	260	300	340	380	6	57
17	62	100	140	190	240	280	330	380	420	6	54
18	66	110	160	210	260	310	370	420	470	6	58
19	71	120	170	230	290	350	410	460	520	6	69
20	77	130	190	260	320	390	450	510	580	6	53
21	84	140	210	280	360	430	500	570	640	7	52
22	92	160	240	310	400	480	550	630	710	7	49
23	100	180	260	350	440	530	610	690	780	8	47
24	120	200	290	390	490	590	670	770	860	8	52
25	130	220	330	430	540	650	740	850	940	9	30
26	140	240	360	480	600	710	810	930	1,030	10	35
27	160	270	400	530	660	780	890	1,020	1,120	10	32
28	180	300	450	590	730	860	980	1,110	1,220	11	29
29	200	330	490	650	800	940	1,080	1,210	1,330	11	18
30	220	370	530	710	870	1,020	1,180	1,330	1,460	12	19
31	....	400	580	770	950	1,110	1,290	1,450	1,620	13	20
32	....	440	630	830	1,030	1,210	1,410	1,600	1,800	13	7
33	....	480	680	900	1,110	1,320	1,540	1,750	1,980	14	9
34	....	510	730	970	1,200	1,430	1,670	1,900	2,150	14	3
35	....	550	790	1,050	1,290	1,540	1,800	2,050	2,320	15	2
36	....	590	840	1,120	1,380	1,660	1,930	2,200	2,490	16	4
37	....	....	900	1,190	1,480	1,770	2,060	2,350	2,650	16	4
38	....	....	960	1,270	1,580	1,890	2,200	2,500	2,820	17	3
39	....	....	1,010	1,350	1,680	2,000	2,340	2,650	3,000	17	....
40	....	....	1,070	1,420	1,780	2,120	2,480	2,810	3,180	18	1
41	....	....	1,130	1,500	1,880	2,250	2,630	2,990	3,370	19	....
42	....	....	1,190	1,580	1,990	2,380	2,780	3,170	3,570	19	1
43	....	....	1,260	1,660	2,090	2,520	2,950	3,380	3,790	20	....
44	....	....	1,320	1,750	2,200	2,660	3,130	3,610	4,000	20	1
											918

TABLE 44.—*Volume in cubic feet of stem wood, exclusive of bark, of BLACK ASH trees of different diameters and heights, 75 to 300 years in age; and factors to multiply by to reduce to cubic feet, including bark.*

Diameter breast-high.	Total height of tree—feet.						Factors to multiply by to reduce to cubic feet, including bark.	Basis.
	60	70	80	90	100	110		
	Peeled volume—cubic feet.							
Inches.								*Trees.*
6	5.4	6.3	7.2	....	....	....	1.22	....
7	7.3	8.5	9.7	....	....	....	1.21	2
8	9.4	11.0	12.6	....	....	....	1.21	4
9	11.9	13.9	15.8	....	....	....	1.20	6
10	14.9	17.3	19.8	....	....	....	1.20	8
11	17.8	21.0	24.0	....	....	....	1.19	5
12	21.0	25.0	28.0	32	....	....	1.19	10
13	25.0	29.0	33.0	37	....	....	1.18	16
14	29.0	34.0	39.0	43	....	....	1.18	4
15	33.0	39.0	44.0	50	....	....	1.17	9
16	38.0	44.0	50.0	57	63	....	1.17	12

TABLE 44.—*Volume in cubic feet of stem wood, exclusive of bark, of BLACK ASH trees of different diameters and height, 75 to 300 years in age, etc.*—Continued.

Diameter breast-high.	Total height of tree—feet.						Factors to multiply by to reduce to cubic feet, including bark.	Basis.
	60	70	80	90	100	110		
	Peeled volume—cubic feet.							
Inches.								*Trees.*
17	43.0	50.0	57.0	64	71		1.16	4
18	48.0	56.0	64.0	72	80		1.16	7
19		62.0	71.0	80	89		1.15	5
20		69.0	78.0	88	98	108	1.15	3
21		76.0	87.0	98	108	119	1.14	8
22		83.0	95.0	107	119	131	1.14	2
23		91.0	104.0	117	130	143	1.13	2
24		99.0	113.0	127	141	155	1.13	1
25			123.0	138	153	169	1.12	2
26			133.0	149	166	183	1.12	1
27			143.0	161	179	197	1.12	2
28			154.0	173	193	212	1.11	1
29			165.0	186	207	227	1.11	1
30			177.0	199	221	243	1.11	1
								116

TABLE 45.—*Volume of stem in cords,*[1] *including bark, of BLACK ASH 75 to 300 years in age, for trees of different diameters and heights, and per cent of bark in trees of different diameters.*

[Based on taper table.]

Diameter breast-high.	Total height of tree—feet.						Bark.	Basis.
	60	70	80	90	100	110		
	Volume—cords.							
Inches.							*Per cent.*	*Trees.*
6	0.066	0.077	0.088				18.0	
7	.088	.103	.117				17.6	2
8	.114	.133	.152				17.2	4
9	.143	.167	.190				16.8	6
10	.179	.208	.238				16.4	8
11	.212	.248	.283				16.0	5
12	.253	.296	.338	0.381			15.7	10
13	.293	.342	.391	.440			15.3	16
14	.341	.398	.454	.511			14.9	4
15	.388	.453	.518	.583			14.5	9
16	.442	.516	.590	.663	0.737		14.2	12
17	.495	.578	.660	.742	.825		13.8	4
18	.554	.647	.739	.832	.923		13.5	7
19		.714	.815	.918	1.019		13.1	5
20		.790	.903	1.015	1.128	1.241	12.8	3
21		.865	.990	1.113	1.236	1.360	12.4	8
22		.948	1.083	1.219	1.354	1.490	12.1	2
23		1.028	1.175	1.322	1.469	1.617	11.8	2
24		1.118	1.277	1.437	1.597	1.756	11.4	1
25			1.375	1.547	1.718	1.891	11.1	2
26			1.487	1.673	1.859	2.046	10.8	1
27			1.605	1.805	2.006	2.206	10.5	2
28			1.711	1.924	2.138	2.352	10.2	1
29			1.834	2.063	2.293	2.582	9.9	1
30			1.962	2.208	2.453	2.697	9.6	1
								116

[1] To reduce to cubic feet, including stump, multiply the number of cords in each case by 100.

TABLE 46.—*Volume, in board feet, of BLACK ASH, 75 to 300 years in age, for trees of different diameters, and number of logs, scaled by the Scribner log rule.*

[Based on taper curves; scaled mostly as 16.3-foot logs, with a few shorter logs where necessary. Height of stump, 1 foot. Measurements taken in New Hampshire, New York, Michigan, and Indiana.]

Diameter breast-high.	Number of 16-foot logs. Volume—board feet. 2	2½	3	3½	4	4½	5	5½	6	Diameter inside bark of top.	Basis.
Inches.										*Inches.*	*Trees.*
8	38	52	65							6	4
9	42	57	72							6	6
10	47	63	80	100						6	8
11	53	70	90	120						6	5
12	59	80	100	130	160					6	10
13	66	90	110	150	180					6	16
14	74	100	130	170	200	230				6	4
15	83	110	150	190	230	260				6	9
16	93	130	170	210	250	290	340			6	12
17		140	190	240	280	330	370			6	4
18		160	210	270	320	360	420	460		6	7
19		180	240	300	360	400	460	510		6	5
20		190	270	340	400	450	510	570	610	6	3
21			300	380	440	500	570	630	680	7	8
22			340	430	500	560	630	700	750	7	2
23			380	490	560	630	700	770	830	8	2
24			430	550	630	710	770	850	920	9	1
25				620	700	790	860	940	1,020	9	2
26				690	780	870	950	1,030	1,120	10	1
27				770	860	960	1,040	1,130	1,220	10	2
28				850	950	1,050	1,140	1,240	1,340	11	1
29				930	1,040	1,140	1,240	1,350	1,450	11	1
30				1,020	1,130	1,230	1,340	1,460	1,570	12	1
											114

TABLE 47.—*Yield of planted groves of GREEN ASH in South Dakota.*[1]

Locality.	Age of grove.	Average height of trees.	Area of plot.	Number of trees per acre.	Total yield per acre.	Average annual yield per acre.	Estimate of posts, stakes, and fuel wood. First-class posts, 4-inch to 6-inch.	Second-class posts, 3-inch to 6-inch.	Stakes, 2-inch to 3-inch.	Fuel wood in addition.
	Years.	*Feet.*	*Acres.*		*Cords.*	*Cords.*	*Number.*	*Number.*	*Number.*	*Cords.*
Ethan	8	16	0.1	1,020	2.24	0.28				
Wentworth	14	16	.5	508	2.18	.15			210	4.05
Lake Preston	14	20	.3	730	4.43	.32		170	570	.66
Hamlin	14	22	.5	1,160	6.58	.47		302	510	3.34
Olivet	18	25	.1	1,200	9.90	.55		400	910	3.10
Sioux Falls	19	33	.5	238	9.62	.51	232	238	122	1.30
Do	20	30	.1	824	7.28	.36	170	170	590	2.40
Viborg	20	26	.1	1,140	7.50	.38		310	850	2.30
Hartman	20	33	.2	400	6.55	.33	250		545	.73
Lake Preston	20	26	.5	942	9.52	.48		190	810	3.10
Dell Rapids	20	27	.1	680	7.90	.40	140	140	380	2.80
Hooker	22	27	.2	1,665	12.20	.55		375	1,020	4.65
Lisle	23	24	.2	1,010	5.30	.23		130	665	1.55
Canastata	23	18	.1	2,550	7.00	.30			660	3.90
Davis	25	23	.2	940	3.80	.15		10	680	.90
Blackmer	25	29	.1	830	10.40	.42		700	700	2.60
Cottonwood	34	47	.2	495	23.55	.69	870	645	600	1.50

[1] Based on average measurements taken in 1904 by Fetherolf.

TABLE 48.—*Yield of planted groves of GREEN ASH in Nebraska.*[1]

County.	Area of grove.	Age of grove.	Dominant trees.		Yield per acre.				
			Average diameter breast high.	Number of trees per acre.	Fuel wood.		Posts.		
					Total.	Average annual.	Firsts.	Seconds.	Total.
	Acres.	*Years.*	*Inches.*		*Cords.*	*Cords.*	*Number.*	*Number.*	*Number.*
Jefferson	1.30	17	3.1	540	3.2	0.2	....	35	35
Washington	2.50	17	4.7	1,083	15.4	.9	310	430	740
Nemaha	1.00	18	3.7	1,054	18.4	1.0	442	494	936
Polk	.92	19	4.2	965	9.8	.5	130	365	495
Colfax	1.50	19	2.9	844	6.1	.3	28	172	200
Hall	2.50	20	2.4	1,304	8.4	.4	20	28	48
Clay	3.43	20	4.2	1,446	11.2	.6	30	232	262
Otoe	3.00	21	4.5	744	11.8	.6	290	464	754
Hamilton	2.50	21	4.2	932	11.8	.6	167	312	488
York	7.00	21	4.2	714	11.7	.6	288	502	790
Fillmore	.99	21	3.7	928	11.3	.5	218	294	512
Polk	1.20	21	4.9	725	14.7	.7	300	317	617
Kearney	1.04	21	6.2	805	18.7	.9	702	504	1,206
Richardson	.80	21	4.3	1,192	24.0	1.1	1,072	584	1,656
Johnson	.95	22	5.1	492	7.4	.3	228	312	540
Saunders	1.56	22	4.8	446	7.5	.3	138	188	326
Hamilton	1.10	23	5.3	496	15.6	.7	294	280	574
York	1.70	23	4.7	835	17.3	.8	425	410	835
Webster	6.60	25	3.8	517	4.0	.2	51	155	206
Fillmore	4.24	25	5.7	345	12.4	.5	190	111	301
Lancaster	.48	25	5.3	497	14.8	.6	327	240	567
Polk	3.10	27	6.2	309	11.6	.4	441	208	649
Butler	.38	29	4.9	950	20.1	.7	490	480	970
Clay	5.30	30	5.8	352	10.0	.3	246	184	430
Saunders	1.50	30	6.1	368	19.3	.6	1,068	370	1,438
Do	1.10	30	7.4	236	26.4	.9	1,162	486	1,648
Do	1.50	32	4.6	553	12.9	.4	343	330	673
Cuming	.25	33	4.6	530	14.8	.5	465	420	885
Saunders	3.10	33	7.0	383	18.9	.6	1,040	420	1,640

[1] From Circular 45 of the Forest Service.

TABLE 49.—*Yield of GREEN ASH plantations in the Plains States.*[1]

Age.	Height.	Total value of posts.	Value of post per acre per annum.		Firsts and seconds.	Trees per acre.
			Without interest on the investment.	4 per cent interest on the investment.		
Years.	*Feet.*				*Per cent.*	*Number.*
19	28	$147.10	$7.74	$5.32	25.5	1,000
23	30	272.50	11.85	7.44	39.3	1,274
23	22	137.20	5.97	3.75	41.6	908
25	49	270.90	10.84	6.51	49.7	680
35	25	135.00	3.86	1.83	42.7	436
40	53	240.45	6.01	2.53	67.5	500
40	45	250.60	6.26	2.64	70.5	535

[1] From Bulletin 86 of the Forest Service, by Carlos G. Bates.

NOTE.—The following conclusions were drawn from the above table: (1) Highest financial returns in 25 years. (2) Ash posts of best quality only at much greater age. (3) Best posts with closest spacing; without this, trees crooked, branchy, and knotty. (4) Should not be planted on dry sites, as the growth is too retarded.

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EXCAVATING MACHINERY USED IN LAND DRAINAGE.

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CONTENTS.

INTRODUCTION.

The excavation of nearly all drainage ditches, other than mere field drains, and a large part of the levee work are now done by power machinery. In the carrying out of community drainage projects in agricultural districts it is often the case that persons upon whom must devolve the ultimate responsibility for the correct design and proper prosecution of the work are but little experienced in the applicability of the different types of excavating machines, and have little practical knowledge of the methods and cost of operation of such machinery. This is frequently true of county drainage commissioners, drainage district commissioners, and of local engineers who, though of limited experience in the technicalities of ditch and levee construction on a large scale, are nevertheless, by virtue of their office, called upon to originate or pass upon plans for drainage improvements, draw up specifications, and award contracts. It is for the purpose of supplying information that would be useful in such cases that this bulletin has been prepared.

In obtaining the information embodied in this bulletin the writer has been aided materially by data furnished by private engineers in charge of improvements and by various contractors and manufacturers.

NOTE.—This bulletin is of interest to those who have to do with the installation of systems of drainage; it is suitable for distribution in the eastern part of the United States.

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The various publications of the different manufacturers of excavating machinery have also been freely consulted, and a number of projects under construction have been inspected.

DEVELOPMENT OF EXCAVATING MACHINERY.

Open drains were no doubt dug on wet agricultural lands during the early settlement of this country. Since only hand tools were then in use, the ditches were small. If the channel was too large to permit the material to be dug and thrown out in one operation, it was necessary to rehandle the dirt with shovels or to carry it out in baskets or wheelbarrows. These methods were very slow and expensive. Although the ditches then constructed served their purpose for the small agricultural tracts which were generally on high ground, the increase in population and the resulting spread of agricultural operations to the lower lands soon demanded the construction of larger channels. Teams and scrapers were then used where conditions permitted. If the material was hard it was first loosened with a plow and then removed by means of slip or wheel scrapers. This method, however, became too expensive as larger ditches were required. Moreover, drainage channels must frequently be constructed on lands so wet and soft as to preclude the use of teams. The increasing demand for suitable excavating machinery has engaged the attention of many men of mechanical bent, and the result has been the invention of modern types of machinery, the development of which has been rapid. By the use of modern machinery the cost of drainage work has been so reduced as now seldom to afford valid excuse for failure to drain.

Perhaps the first successful use of power machinery in drainage work was on a project in Illinois in 1882 when a floating dredge was used for digging the channels. During the early development manufacturers entered their machines in contests for medals offered for the best digging machines. Thus in 1886, three dredging concerns entered their machines in such a contest before the Illinois State Board of Agriculture.

The early type of dipper dredge was equipped with the old-fashioned vertical spuds, and the hull was built wide to prevent tipping. The ditches desired at that time were usually small and owing to the width of hull the operator was nearly always compelled to excavate more material than he was paid for. The bank spud, which runs directly from the side of the machine to the bank, was invented to do away with this unnecessary width of hull and the consequent useless excavation. Although many delays and difficulties were encountered in the early stages of development, the cost of excavation by machinery was soon reduced far below that by hand labor. This period marks an epoch in the progress of drainage in this country.

In late years the so-called dry-land excavators of various types have been developed and have reduced the cost of excavation under conditions to which floating dredges are not adapted. The growth of the drag-line scraper excavator has been especially prominent. At present this machine probably has a wider field of usefulness than any other type of excavator made.

The cost of all kinds of excavation has now reached a very low figure as compared to the prices prevailing for work by machinery only a few years ago. This has mainly been brought about by the entrance into the contracting field of many men equipped with modern machinery who, through the keen competition, have taken contracts at prices permitting only a small margin of profit.

THE FLOATING DIPPER DREDGE.

The floating dipper dredge is probably the oldest and most widely used type of machine for the excavation of drainage ditches. The essential parts are the hull, engines, boiler, A-frame, swinging circle, spuds, boom, and dipper. With the exception of the dipper these parts appear in some form on every type of floating dredge used for ditching. Various manufacturers have different patented details of construction, but the general principles of construction and operation are the same on all floating dipper dredges.

ESSENTIAL FEATURES OF CONSTRUCTION.

HULL.

The hull may be either of wood or of steel; the use of the latter material will undoubtedly constantly increase in the future owing to the ever-increasing cost of timber that is suitable for building hulls. The many difficulties met with in the operation of the earlier machines have taught manufacturers that certain fixed relations exist between the dimensions of the hull and the positions and weights of the other parts of the dredge. Unless these relations are considered in the design of the hull much trouble will result in the operation of the dredge. The smaller dredged ditches are generally constructed by machines with from 1 to 1½ yard dippers. The machinery necessary for operating these sizes being comparatively light, the hulls are of such dimensions that they can easily be floated in the smaller channels, although the width of hull used for a machine of given capacity varies somewhat with the different manufacturers. Some dredges are so designed that the thrust of the dipper, when digging, is carried directly from the A-frame through the spud arm to the spud shoe and the bank of the ditch. By this arrangement a slightly narrower hull can be used than is necessary where the machine is differently designed.

A dipper dredge to withstand the severe stresses due to the constantly changing loads must be very strongly built. If the hull is of wood it is made up of a strong frame work of timbers planked on the sides and bottom with 3-inch (or heavier) planks. It is always strengthened with numerous cross trusses inside, to prevent buckling. The front end of the hull should always be of double thickness to prevent damage and possible sinking through the dipper striking the hull.

In the larger sizes of dredge built at the present time the common practice is to make the hull of the same width, top and bottom. On some of the smaller machines, especially those with steel hulls, the top is made wider than the bottom. Hulls must be very carefully caulked, since in operating the dredge the strain on the hull will tend to loosen any poor caulking.

It often becomes necessary to dismantle a dredge in order to move it from one project to another. Wooden hulls, because of the necessity of their being so strongly built, are practically destroyed by being taken down, and it is in many instances cheaper to build a new hull than to move and rebuild the old one. To save this expense steel hulls are used to some extent on the smallest-sized machines, although they have not been generally favored for the larger dredges. On some of the small one-half yard or three-fourths yard dredges the hull has been made in sections, which can be taken apart and hauled or shipped to another project. This method, however, is not adapted to the larger machines.

The machinery of a dredge is ordinarily placed on the deck of the hull. It is, however, sometimes placed below the deck in order to gain head room. Sometimes the boiler and coal bins are placed on a deck from 1 to 3 feet lower than the main deck.

ENGINES AND BOILER.

The power most commonly used on dipper dredges is steam, although a number of machines are now in operation which are equipped with internal-combustion engines or electric motors. The majority of dredge operators are more familiar with steam plants than with oil engines. Also, steam power has the advantage of being good for from 50 to 100 per cent increase over its rated capacity.

Internal-combustion engines are generally run on either gasoline, kerosene, naphtha, or distillate oil. Practically all of the dredges equipped with this type of engine are of the one-half yard or 1-yard size, although it has been used in at least one instance on a 3-yard machine. An internal-combustion engine is usually rated at its actual capacity. Therefore, when replacing a steam engine with a gas engine, it is a good plan to put in a plant with from 50 to 75 per cent greater power than the rating of the steam engine which it is to replace. Contractors as a rule do not consider internal-combustion engines as suitable for operating machines which have such constantly changing loads as is the case with dipper dredges.

Owing to the constant jar and pound on the hull the vertical engine is not so well adapted to excavating machinery as the horizontal type. On a large dredge an independent engine unit is used for each of the operations of swinging, hoisting, and handling spuds. The hoisting and swinging engines are generally of the horizontal, double-cylinder type and must be self-contained on a cast-iron or structural-steel bed plate. Steam engines are generally designated by the dimensions of their cylinders rather than by the horsepower they develop.

Owing to the cost of fuel, the expense of transporting it to the dredge, and the impure and muddy water that must be used in some cases, the size and type of boiler must be selected with great care. The boiler commonly used is the locomotive type with either open or water bottom. Vertical boilers have been used in dredges of the smallest sizes, but are not economical in the consumption of fuel. The grate area of the locomotive-type boilers is ordinarily less than that for the same size of Scotch marine boiler. The return-flue Scotch marine boiler is used on many dredges and meets with great favor. The earlier boilers were designed for a pressure of 100 pounds. Later this was increased to 150 pounds and the boiler was worked at 100 pounds or more pressure. The size of boiler should be at least 25 per cent greater than that theoretically required to operate the engines. Owing to the foul character of the water that must often be used, the boiler should have two separate and distinct boiler feeds, either injectors or pumps. A great saving of fuel can be effected by covering the boiler and steam pipes with asbestos. Either wood or coal is used for fuel.

A-FRAME.

The A-frame is a tower composed of timber or steel members securely anchored on the deck of the hull near the front and joined at the top by a cast-steel head or yoke. (See Pl. I.) The A-frame may have either two or four legs. In the latter case the two front or main legs are set in a vertical plane. If only two legs are used they are inclined slightly forward. The A-frame must be strongly guyed and held rigidly in position, as the severe stresses from the outer and loaded end of the boom are carried by the top of this tower. Failure of any part of the A-frame may result in serious damage to the dredge and even in loss of life. The height is governed by the required elevation of the end of the boom, which in turn is determined by the depth of excavation and the distance at which the excavated material must be placed. On the top of the head block is a large pin on which the yoke revolves, this latter being a short beam to the ends of which are attached the cables which support the outer end of the boom.

SWINGING DEVICE.

The swinging device used on the different makes of dredge varies greatly. In some cases it consists of a circular, double-channel frame, firmly anchored to the deck, with several sheaves bolted at intervals in the circumference of the frame to carry the cable that travels over them in swinging the boom. In this fixed type of swinging device a large diameter of circle can be used. There is also the movable type of swinging circle. This generally consists of a solid iron circle mounted on a pivot. The heel of the boom is over the point of the pivot and the boom is braced to the circle. This type requires more deck room than does the first named type. The turntable may be placed on deck (Pl. I, fig. 1) or overhead (Pl. I, fig. 2), but the deck plan is generally used.

Independent engines may be used for swinging the boom or power may be obtained from the main engine to drive the swinging drums. If this latter plan is followed two independent friction drums are attached to the bed plate of the engine and geared so as to be driven by it. If internal-combustion engines are used, independent friction drums are necessary for the various operations of the dredge. The common practice on large steam-operated machines is to have independent swinging engines.

SPUDS.

Spuds are heavy timber or steel members, the purpose of which is to hold the dredge in position while operating. One is placed on each side near the front and the third in the center line of the boat at the stern. Vertical spuds extend directly downward at the side of the hull and rest on the bottom of the excavated channel. They are used on deep-water dredges or for excavating large channels.

For a dredge with a narrow hull bank spuds, which extend outward and rest on the ground surface, are preferable, since they give a large bearing surface and the footing is usually on solid ground. These are important features, as a longer boom and a larger bucket can then be used on a narrow hull.

There are various patented types of bank spuds. One is the convertible bank-and-vertical power spud. This type can easily be changed from a bank into a vertical spud and is most convenient in crossing old channels, digging cut-offs, or making a double cut. Another type is the telescopic bank spud, so designed that the spud is either lengthened or shortened by means of a telescopic device. There are other styles of bank spuds, which, although they possibly do not have as wide a range as the telescopic type, can, nevertheless, be operated successfully several feet above or below the water surface. Plate I, figure 1, shows a dipper dredge equipped with telescopic bank spuds.

The vertical spuds of various makes are more nearly alike. The rear spud is always of the vertical type and is used to keep the stern of the boat from swinging from side to side as the dredge is operated. The spuds are usually raised and lowered by steel cables connected with the engine. On large machines they are sometimes operated by means of a steam cylinder placed in front of each spud, with a movable clamp or shoe encircling the spud and attached to the piston of the cylinder; this method is, however, wasteful of steam and expensive. Sometimes compressed air is used to aid in releasing the foot of the spud from the mud; less power is thus required to raise the spud. All types of spuds must be equipped with a strong locking device; they must also be so designed that little time is lost in raising or lowering them. A dipper dredge with vertical spuds is illustrated in Plate I, figure 2.

BOOM.

The boom is built either of steel or of wood. In the former case it is made of standard structural sections strongly riveted together. If of wood, it is generally of the "fish-bellied" shape. Some types of long booms are of the open or "knee" build, with a solid filler at the lower end and the chords sprung over posts and cross bulkheads (Plate I, fig. 1). This construction reduces the wind pressure when swinging. Practice has taught that the length of boom must bear a definite relation to the width of the hull. Even on a large dredge it is not advisable to have a boom longer than 80 to 90 feet, although the manufacturers will build them 100 feet long if desired. Large dredges with long booms are much slower in operating than are the smaller-sized dredges. The same number of men are required in either case.

The lower end of the boom is pivoted. The upper and outer end is connected to the yoke at the top of the A-frame by means of adjustable wire cables. A sheave placed at the outer end of the boom carries the cable leading from the dipper through the fair-lead sheaves at the lower end of the boom and thence to the hoisting drum.

On the early type of dipper dredge, chains were used for hoisting and backing. These were hard to install and would break without warning. Steel cable has entirely replaced the old chain since it is less expensive, easier to install, clean, and noiseless; also its weakening, due to wear, is more apparent and accidents are therefore less likely.

DIPPER AND DIPPER HANDLE.

The dipper handle which carries the dipper at its lower end is made either of steel or of wood. On its under side is a cog rack which moves over pinions mounted on the upper side of the boom. It must be made of sufficient stiffness to prevent bending when the dipper is being filled.

On dredges such as are ordinarily used in drainage work, the dipper or bucket varies in size from one-half cubic yard to 4 or 5 cubic yards. The dipper varies considerably in shape with the different manufacturers. For work in ordinary material the cutting edge is made of a single steel plate, preferably of manganese steel, but if the material is hard large steel teeth are used to reinforce the cutting edge. The bottom of the dipper is a heavy steel plate which is hinged to the back and is held in place by a spring latch on the front of the dipper. The latch is operated by the craneman, who thus dumps the contents of the dipper. As the latter is lowered into the ditch the weight of the bottom causes it to close and latch automatically.

The larger the dipper used, the larger must be the engine and boiler, and, in fact, all of the parts, including the hull. Thus the size of a dipper dredge is determined by the capacity of its dipper.

COST.

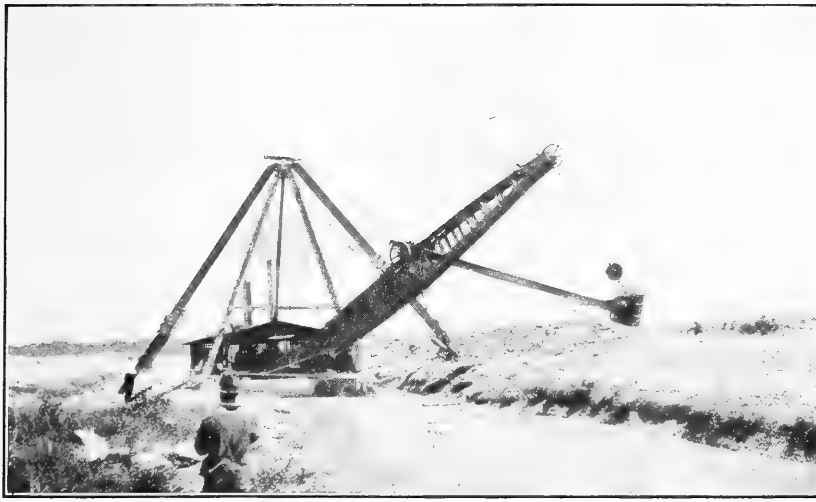
The cost of dredges advances rapidly as the size and capacity are increased. Dredges of the same rated capacity also vary somewhat in cost with the different manufacturers. All of the machinery is usually made at the shops of the manufacturer. The material for the hulls may also be supplied by the manufacturer, but usually the purchaser obtains lumber in the open market and builds the hull in the field. The cost of hauling the material and machinery from the railroad to the place of erection, the local price of labor, and the conveniences for housing and feeding the workmen are factors which will enter into the cost of a machine of any type. It requires at least two cars to transport the material for a small dipper dredge, while for a machine of large size from four to six cars are required.

The following table gives the approximate costs of the various sizes of dredges ready for operation, though these would be largely affected by the difficulties and expense of transporting the material and assembling the machine:

Approximate costs of dipper dredges.

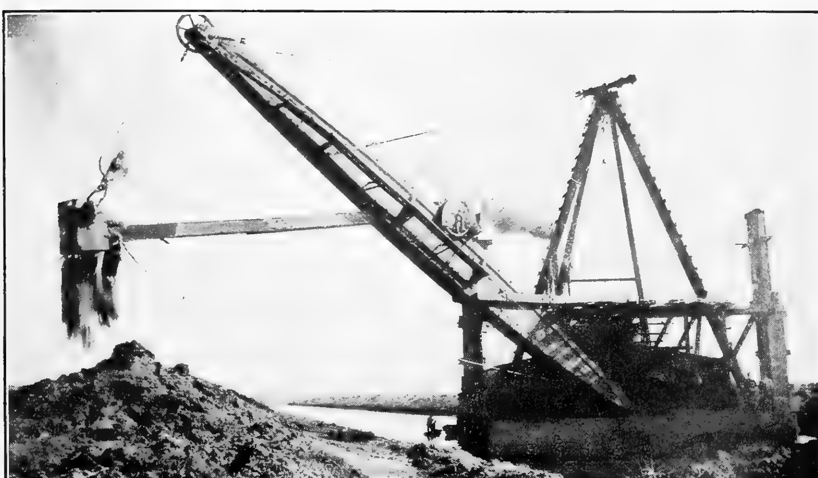
Size.	Cost of machinery.	Cost of wood hull.	Total.
¾-yard	$3,700	$1,800	$5,500
1-yard	5,400	2,200	7,600
1¼-yard	6,100	2,250	8,350
1½-yard	7,100	4,500	11,600
2½-yard	14,000	9,000	23,000

It requires practically a month for ten men to erect a 1-yard dredge, 6 weeks to erect a 1½-yard or 1¾-yard dredge, and 8 weeks to construct a 2-yard or 2½-yard machine. It requires less than one-half the time given above to dismantle a machine. A 1-yard dredge which cost



DI4421a

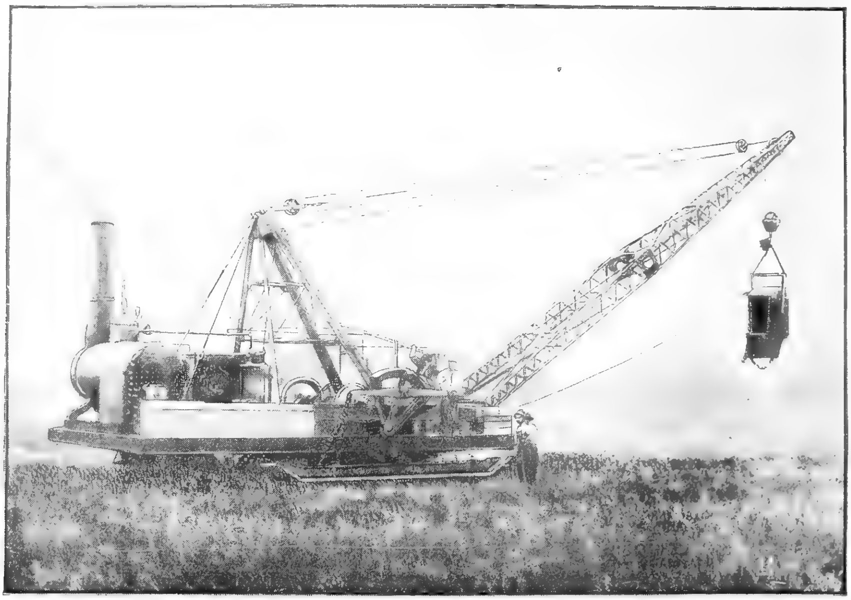
FIG. 1.—DREDGE EQUIPPED WITH BANK SPUDS.



DI4807b

FIG. 2.—DREDGE EQUIPPED WITH VERTICAL SPUDS.

TYPES OF FLOATING DIPPER DREDGES.



D12391

FIG. 1.—MACHINE IN POSITION FOR DIGGING.

D12392

FIG. 2.—MACHINE IN THE ACT OF MOVING.

A WALKING SCRAPER EXCAVATOR OF THE ROTARY TYPE.

$8,000 was shipped about 400 miles and hauled by wagon 18 miles. The dismantling cost about $490; the freight charges were about $700; hauling, $360; and rebuilding about $670. These costs are fairly representative for this size of machine.

METHOD OF OPERATING.

With a floating dredge the construction should, where practicable, begin at the upper end of the ditch and proceed downstream. Sometimes it is not feasible to transport the machinery and material to the upper end of the ditch and the dredge must then work upstream. This is undesirable, unless the fall be slight, since in working upstream dams must be built behind the boat to maintain the necessary water level. In working downstream the ditch remains full and the dredge, floating high, can dig a much narrower bottom than if working upstream in shallow water. Moreover, when floating low, the dipper may not properly clear the spoil bank. Again, in working downstream, any material dropping from the dipper into the ditch will be taken out in the next shovelful; whereas if working upstream any material dropped or any silt washed behind the dredge is left to settle in the bottom of the ditch. If work is begun on the natural ground surface a pit must be dug to launch the boat; or if in a stream, it may be necessary to build a temporary dam in the channel to raise the water high enough to float the boat. The depth of water required varies from 2 feet upward depending on the size of machine.

The floating dipper dredge moves itself ahead by means of the dipper. The spuds are first loosened from their bearings and the dipper is run ahead of the machine and rested on the natural ground surface in front of the ditch. The spuds are then raised and the engines operating the backing drum are started; the dredge, being free, is thus pulled ahead. The spuds are then lowered and excavation continued.

In timbered country the right of way must be cleared. In many cases the timber cut will supply sufficient fuel for the dredge. It is poor policy to fall the trees and leave them on the ground to be removed by the dredge. The stumps should always be shattered with dynamite, as the strain on the machinery is thus rendered much less and the life of the dredge increased.

An engineer, a craneman, a fireman, and a deckhand are required to operate a dipper dredge. The output, loss of time due to breakdowns, and the cost of repairs, depend almost wholly upon their skill and efficiency. The engineer should be an all-around mechanic as well as experienced in dredging.

The amount of fuel consumed depends upon the size and type of boiler used, and upon the burning and heating qualities of the fuel.

A very great saving can be effected by covering the boiler with an asbestos coat. Ordinarily, about 25 pounds of coal per horsepower-hour are consumed on dredges. The cost of repairs depends largely upon the operator; a careless operator will cause many unnecessary breakdowns. It is not only the high cost of repairs for machinery but also the time lost which aids in increasing the actual cost of the output. It is a well-established fact that it is not the initial cost of a dredge or of any machine, but the operating and overhead expenses, that reduce the profits.

COST OF OPERATION.

The cost of dredge work depends upon a number of factors. The locality of the work, the kind of soil, repairs, delays, labor, etc., greatly influence the actual cost of any work. If the water level can naturally be maintained within a foot or so of the surface of the ground, the cost of excavation can be reduced very low with this type of machine. The data given in the following pages were obtained from the actual cost records of the various projects. Unfortunately, the figures are not always strictly comparable, one project with another, owing to variations in the items of cost included. Unless otherwise stated, interest is taken at 6 per cent and depreciation at 35 per cent per annum on the cost of the dredging outfit. Interest and depreciation are, however, charged only for the interval of time upon which the unit cost is based. This is not strictly correct, as a certain amount of time consumed in getting the machine on and off the work should be charged to each project. In most cases it was impossible to ascertain the time that should be charged to moving, building, etc., and therefore the item has been ignored in all cases, for the sake of uniformity. On some projects figures for operation over an extended period were not obtainable. In such cases the unit cost is based upon the daily cost of operation and the average amount of ditch dug per day, no allowance being made for interest and depreciation.

In the construction of a ditch in North Carolina a new 1¼-yard dipper dredge was employed. This dredge had a 5 by 20 by 70 foot hull and was equipped with 8⅜ by 10 inch double-cylinder hoisting engines; 7 by 7 inch double cylinder, reversible swinging engines; a 50-horsepower Scotch marine return-flue boiler; a 1¼-yard dipper, 31-foot dipper handle, and 45-foot boom. The spuds were convertible to bank or vertical and were operated by the hoisting engines. The cost of this dredge, erected, was $10,342.19. The dredge was operated continuously, each shift working 11 hours per day. The men were paid at the following rates per month: Superintendent in charge, $110; engineers, $100; cranemen, $60; firemen, $48; deck-hands, $36. The men furnished their own subsistence. The ditch was 9½ miles long and ranged from 22 to 30 feet wide on top and from 8 to 10 feet deep; it had side slopes of ½ to 1 and a berm 8 feet wide. The water level was easily maintained near the ground surface. Very little right-of-way clearing was required. In the construction of this ditch the dredge excavated 350,720 cubic yards of earth. One year was required for the dredge to complete this work. The following cost data were taken from the records of the drainage district which owned and operated the dredge:

Cost of operation, including labor and fuel	$15, 889. 01
Repairs	1, 948. 24
Interest and depreciation	4, 240. 22
	22, 077. 47

Cost per cubic yard, $0.0629.

A new dredge of the same size and type as the one just described was used in the excavation of a drainage ditch in the same locality as the foregoing project. The ditch followed an old creek channel for the greater part of its length. The cost of the dredge, erected, was $9,365.34. It was operated in one shift of 11 hours; the actual time of operation was not recorded. The crew and the rates of pay were the same as in the foregoing example. The ditch was 3¾ miles long and ranged in top width from 22 to 26 feet and in depth from 6 to 10 feet. The side slopes were ½ to 1; the berm was 8 feet wide. The dredge worked downstream and the water level was easily held near the ground surface. Practically no right-of-way clearing was done. The material excavated was a loam top soil underlain by stiff clay; very little rock was encountered. The cost of the work was considerably affected by the expense ($1,459) of passing three bridges. The total amount excavated in a period of about 10 months was 121,200 cubic yards. The dredge was owned and operated by the drainage district. The following costs were recorded:

Cost of operation, including labor and fuel	$5, 921. 05
Repairs	1, 028. 73
Incidentals	117. 95
Interest and depreciation	3, 199. 80
	10, 267. 53

Cost per cubic yard, $0.0847.

A dipper dredge with a 5½ by 16 by 60 foot hull, 7 by 8 inch double-cylinder hoisting engines, friction swing, 1-yard dipper, 35-foot boom, and telescopic bank spuds was used in the construction of about 5 miles of ditch in western North Carolina. No reliable information was available as to the amount of material moved; but the following figures as to the cost of installing the dredge are of interest:

Hull: Labor and material	$1,803.23
Machinery:	
Material	4,800.00
Freight	379.10
Drayage	72.60
Installing	310.60
Extra equipment (forge tools, etc.)	80.00
Lighting equipment (engine and dynamo and wiring)	207.00
	7,652.53

In Colorado, a dipper dredge having a 24 by 75 foot hull, 1½-yard dipper, and 50-foot boom, was used in cleaning out and enlarging about 20 miles of canal. The equipment, complete, including cook and bunk boats, cost $16,500. Two shifts of 11 hours each were run. During the year for which the data are given the dredge was actually in operation but 187 days, or 58 per cent of the total working days. The following crew were paid the given rates per month, including board: Head runner, $120; 1 runner, $110; 2 cranemen at $55; 2 firemen at $45; 2 deckhands at $40; 1 teamster, $40; 1 cook, $50. No right-of-way clearing was required. The water for the boiler was taken from the canal, and as a result considerable trouble was experienced from mud and scale. The cost data below are based on the amount of material moved from inside the grade stakes during the year, amounting to 394,387 cubic yards. It was estimated that an excess of 25 per cent was actually moved. The following was the cost of the work for one year:

Operation:	
Labor operating dredge	$6,243.70
Coal, including freight, 1,276.65 tons, at $2.35	3,000.13
Hauling coal, 1,276.65 tons, at 82½ cents	1,053.24
Oil, waste, and miscellaneous supplies	692.80
Cost of controlling water to float dredge	369.24
Repairs, labor, and material	3,894.67
Removing and replacing bridges	837.78
Interest and depreciation	6,765.00
	22,856.56

Cost per cubic yard, $0.058.

Miscellaneous expenses:	
Engineering and supervision	$1,856.10
Building up ditch bank and making road on top	4,721.75
Right of way and legal expenses	190.42
	6,768.27

The cost of the dredging outfit was as follows:

Hull:	
Material	$1,960.83
Labor, including hauling	1,959.99
Machinery:	
Cost, including freight	9,997.72
Hauling and installing	817.55

Cook and bunk boats:	
Material	$663.90
Labor	453.66
Equipment	646.35
Total	16,500.00

In connection with a drainage project in southwest Louisiana a steam-operated, floating dipper dredge, equipped with a 1-yard dipper, 40-foot boom, and convertible power spuds was employed in the excavation of about 10 miles of ditch which varied in width from 18 to 50 feet and in depth from 4 to 6 feet; 15-foot berms were specified. The cost of the dredge on the work is said to have been $10,000. Two shifts of 10 hours each were run, but the actual number of days of operation was not recorded. The crew and monthly rates of pay, including subsistence, were as follows: Two runners, at $100; 2 cranemen, at $60; 2 firemen, at $60; 1 deckhand, $40; 1 cook, $30, The material excavated was a hard, stiff clay. The total amount excavated in about 8 months was 147,000 cubic yards. The average cost, per month, of operation was as follows:

Labor	$510
Board	100
Coal	262
Repairs	200
Oil and supplies	50
Interest and depreciation	342
	1,464

Cost per cubic yard, $0.0796.

On another project in southern Louisiana there was employed a floating dipper dredge with a 5 by 22 by 73 foot hull; 8 by 10 inch double-cylinder hoisting engine; 6 by 8 inch, double-cylinder reversible swinging engines; 1¼-yard dipper, and 40-foot boom. The machine was equipped with bank spuds. The cost of the dredge, ready to operate, was $13,000. The ditches averaged about 30 feet wide and were from 5 to 6 feet deep. The land was nearly level and the water surface was easily kept within a foot of the ground surface. The material was a top muck underlain by an alluvial mud which was hardly solid enough to hold its shape when dropped from the dipper. There were few submerged logs or stumps. The dredge was operated the year around for 2 years. No record was kept of the actual time of operation. The average output per shift (12 hours) on a 30-foot ditch 5 feet deep was 1,200 cubic yards, at a cost as follows:

Labor (4 men)	$10.50
Fuel, 6 barrels oil, at $1.75	10.50
Repairs, oil, and grease	5.50
	26.50

Cost per cubic yard, exclusive of interest and depreciation, $0.0221.

In the same general locality as the foregoing case, and under the same soil conditions, a 1-yard dredge which was, except in respect to capacity, equipped similarly to the above-described machine, was operated in the construction of ditches which averaged 30 feet wide and 5 feet deep. The cost of the dredge, erected, was $11,000. The average output per 12-hour shift during a 2-years' run was 1,000 cubic yards. The cost per shift was as follows:

Labor (4 men)	$10.00
Fuel, 5 barrels oil, at $1.75	8.75
Repairs, oil, and grease	5.50
	24.25

Cost per cubic yard, exclusive of interest and depreciation, $0.0242.

In another drainage project in southern Louisiana several ditches, each 3 miles long, were constructed by a dipper dredge installed on a 5½ by 18 by 70 foot hull. The power was obtained from a 60-horsepower internal-combustion engine. The dredge had a 1¼-yard dipper, 40-foot boom, and convertible power spuds. The total cost of the outfit, including house-boats and small towboats, was $12,000. Two shifts of 10 hours each were run for 26 days in each month. The crew were furnished subsistence, and each shift consisted of: One runner, at $125; 1 craneman, at $65; and 1 engine tender, at $40 per month. One cook, at $35, and one general utility man, at $60, were also employed, making a total labor cost of $555 per month. The average dimensions of the ditch were: Top width, 25 feet; bottom width, 18 feet; and depth, 8 feet. The ground was nearly level and the water stood about 3 feet below the ground surface. The excavated material was a stiff, sandy clay. About 3.4 miles of the work consisted in cleaning old channel, which required frequent moving and gave small yardage. The total excavation in five months was about 216,000 cubic yards. The cost was as follows:

Labor and board	$3,555
Fuel and oil	2,300
Repairs	980
Interest and depreciation	2,050
	8,885

Cost per cubic yard, $0.411.

A steam-operated floating dipper dredge, mounted on a 5 by 15 by 60 foot hull and equipped with a 1-yard dipper, 38-foot boom, and inclined telescopic bank spuds, was used in the excavation of about 10¾ miles of ditch in North Carolina. The cost of the dredge is stated to have been $6,613.82. One shift of 10 hours per day was run. The actual number of days of operation was not recorded. The crew and rates of pay were as follows: One engineer, $125 per month; 1 craneman, $2 per day; 1 fireman, $1.25 per day; 1 watchman, $1.50 per day. The crew furnished their own subsistence.

The ditch was about 18 feet in top width, 12 feet deep, and had ½ to 1 slopes. It followed an old creek bed for a large part of the distance. The material excavated was a clay, though some rock was also encountered. Based upon the given dimensions of the ditch, the total excavation amounted to 295,000 cubic yards. Eighteen months were required to complete the work. The cost was as follows:

Operation:	
Labor	$6, 310. 94
Fuel	2, 210. 30
Repairs:	
Labor	1, 380. 12
Material	1, 136. 71
Interest and depreciation	4, 067. 00
	15, 105. 07

Cost per cubic yard, $0.0512.

Miscellaneous expenses:	
Engineering	$164. 83
Clearing right of way	282. 70
Rebuilding bridges	104. 96
Incidentals	48. 77
Administration	618. 00
	1, 219. 26

SELECTION OF DREDGE.

The floating dipper dredge is admirably adapted to the excavation of drainage ditches having sufficient width and depth and the necessary supply of water for floating the machine, and especially where the ground is swampy or covered with trees or stumps, rendering impracticable the use of teams or of so-called dry-land machinery. No other type of excavator is so well fitted for digging ditches in a timbered country or where large stumps will be encountered. The dipper dredge, however, is not well adapted to digging channels of less than 100 square feet cross section. Standard types of dipper dredges are not adapted to digging ditches more than 1,200 square feet in cross section, although most makers will build special machines for larger ditches. As ordinarily operated, the dipper dredge constructs a more or less ragged and irregular ditch, but in the hands of a skilled operator very good results can be obtained.

The size of dredge that should be used depends upon various factors. Not only the greatest and least, but also the intermediate cross-sectional dimensions of the proposed ditch should be known, and the relative amount of each class. The specified width of berm and the side slopes should also be known. The total amount of excavation, the nature of the material, and whether the dirt is to be dumped on one or both sides, are factors that must be considered. A knowledge of the depth of water which can be maintained at a minimum expense is also necessary, and information as to the number and size of stumps to be encountered is of the highest importance. Owing to the expense of knocking down, transporting, and setting up a dredge, it is necessary to select or use one of the size that will do the most work at one building. This requires an intimate knowledge of the layout of the proposed work, and of the accessibility of the different portions.

It is the opinion of many contractors that the use of dredges with narrow hulls, say less than 18 feet, is to be avoided except where the ground is so hard that the bank spuds rest firmly and bear the weight of the swinging load; in soft ground it may be cheaper to use a wider hull, even though it be necessary to make the ditch wider than is specified.

The various makers of dredges have compiled and made available to prospective purchasers tables, giving full descriptions of their machines. These tables give for each of the numerous dipper capacities such data as the following: Length of boom and dipper handle; distances machines will dig below water line and dump above water line; distance from center of hull to center of dump; dimensions of hull and amount of lumber required to build; sizes of hoisting and swinging engines; and daily digging capacity of machine. With the aid of these data, and having in mind the ditch specifications and the factors enumerated in the preceding paragraph, the proper size of dredge for a particular ditch may be determined.

Where it will be necessary to cope with stumps, this factor will often be the ruling one in determining the capacity of machine needed.

When designing a ditch, the engineer should always have in mind the type and size of machine to which the work is adapted. So far as is consistent with other considerations a ditch system should be so designed as to give the contractor the greatest amount of excavation for a given size of dredge. This point can best be illustrated by a practical example. A certain ditch was designed with a bottom width varying from 16 to 46 feet, and with a cut of about 7 feet throughout the entire length of 15 miles. The ditch as planned was too wide at its lower end to be constructed by an ordinary-sized dredge, unless equipped with the telescopic or the convertible power spuds. By making the cut deeper at the lower end, the width of the ditch could have been made considerably less and an ordinary dredge could have dug the ditch throughout. The necessity of using two dredges of different sizes on such a comparatively small job of course tended to increase the unit cost of the work. Conditions may, it is true, be such as to make a deeper ditch impracticable, as, for instance, scour due to too great a velocity, the lack of a free outlet, the presence of rock, and other conditions.

In planning drainage for a small area which can be drained by one dredged ditch from 6 to about 12 miles in length, the engineer will frequently make the above-mentioned mistake of designing his ditch too wide at the outlet. On large projects, where the amount of excavation is great, this condition will not occur so often, since there is usually sufficient yardage to warrant the installation of two or more plants. The engineer should remember that if the ditches are so planned that one machine can do all the work, even though the yardage is sufficient to justify two dredges, the cost of construction will be reduced. However, the time required to do the work with one machine may be so great that the district would rather pay the additional cost involved in installing two plants.

A contract may consist of a number of ditches all but one of which are suited to a given size of machine. This ditch is too wide to be cut by the dredge at one cutting, and the yardage is insufficient to justify the installation of another dredge. The difficulty may be overcome by making a double cut. This, however, requires the use of either vertical or the convertible type of spuds.

If the best prices are to be obtained, each 1½-yard dredge on a project should have a minimum of 250,000 cubic yards and each 3-yard dredge not less than 500,000 cubic yards.

THE FLOATING GRAB-BUCKET DREDGE.

In construction the floating grab-bucket dredge differs from the dipper type only in the appliances for handling the material. Instead of using a dipper and dipper handle, an orange-peel or a clamshell bucket is suspended from the end of the boom. The bucket of the orange-peel type is the one more generally used for drainage work.

A much longer boom can be used with the grab-bucket dredge than with the dipper dredge. From 75 to 85 feet is about the maximum length of boom that can be successfully operated on a dipper dredge, while booms as long as 240 feet have been used on grab-bucket dredges. This feature is of especial importance in levee construction, as it is desired to deposit the material as far from the stream as possible.

While the dipper dredge pulls itself ahead by means of the dipper, with a grab-bucket dredge some type of "pull-ahead" line is necessary. Generally three auxiliary drums are provided, which are used for operating the two spuds and for overhauling the pull-ahead line, which is securely fastened to the bucket. The bucket is dropped into the material, the hoisting line is slackened, and the pull-ahead line is drawn taut, thus pulling the dredge ahead. In other cases the pull-ahead line may be anchored to a "dead man" buried some distance ahead of the machine.

Owing to its long reach, the grab-bucket dredge is often used for levee construction. It, however, is not very extensively used for the excavation of drainage channels, although there are certain conditions under which it can be used to greater advantage than can the dipper dredge. It excels in handling the muck found on the prairie lands of southern Louisiana and in certain other localities, and under such conditions is better adapted to ditch and levee construction than is the dipper type. The latter, however, is preferable for digging hard soil and stumps.

THE DRAG-LINE SCRAPER EXCAVATOR.

The drag-line scraper excavator is a type of dry-land machine that has come into prominence only within the last few years. It has made feasible the cheap construction of much larger ditches and levees than is possible by the use of any other type of machine.

In the type most commonly used, the engine platform, engine house, and boom are connected and revolve on a turntable which is secured to a lower platform built up of structural steel sections. This is known as the revolving or rotary type and is illustrated in Plate II. Upon the upper surface of the lower platform is riveted the track upon which the swinging circle revolves, and in its center is the pivot bearing. The turntable is a steel-frame circle supported by several wheels which rest upon the track. The upper platform, which is also built up of standard steel sections, is held to the lower platform by means of a central pivot.

In the stationary type the engine platform is fixed; the boom is pivoted at its lower end and is the only part of the machine which swings. This type is illustrated in Plate IV, figure 2.

The power equipment of the drag-line excavator may be either steam, gasoline, or electric. Unlike the floating dipper dredge, the internal combustion engine has been used with success on drag-line excavators and meets with favor among contractors. For the steam plant the boiler most commonly used is either the locomotive or the Scotch marine return-flue type. On the smaller machines vertical boilers are sometimes employed. The engines used consist of two sets, the main engines and the swinging engines. The former are set in front and are of the horizontal double-cylinder type, with engines and drums self-contained on a single cast-iron or steel bed plate.

Sometimes the swinging is done by a mechanism attached to the main engine. Ordinarily, however, separate swinging engines are provided. In the rotary type these engines drive, through a series of gears, a pinion which engages the circular rack on the lower frame. Where electricity can be secured cheaply the machines can be operated very economically by this power.

In the smaller drag-line machines the boom is generally constructed of two channels with cross bracing, while for the larger machines two cross-braced lattice girders are used. The lower ends of the two main members of the boom are spread apart to give stability, while at the upper end the two members are joined, at which point one or more sheaves are placed. The top of the boom is guyed to the top of the A frame which is located near the front of the main engine. The lower ends of the A frame are bolted to the platform while the upper end is guyed to the rear corners of the platform.

The bucket most frequently used on drag-line excavators is of the scraper type, although the clam-shell and orange-peel buckets are sometimes used for special work. The scraper bucket is connected to the main engine by two steel cables called respectively the hoisting and drag-line cables. The bucket is filled by being pulled toward the machine, and when full is raised by the hoisting cable which passes from the bucket over the sheaves in the end of the boom and down to the hoisting drum. There are many patented devices for quickly dumping the bucket, a feature that is important in digging sticky material. The capacity of the scraper buckets range from about five-eighths cubic yard to 3 cubic yards.

The crew necessary to operate this type of machine consists of two men, an operator and a fireman on the steam machine, or an operator and an oiler on the gasoline or electrically-driven machines. In addition to these, two or more trackmen are required, except in the case of the so-called walking type.

For movement over the ground the drag-line excavator may be mounted on either wheels, rollers, caterpillar tractors, trucks, or walking shoes.

Where the ground is uneven or cut up with old channels and surface ditches, it is necessary in the case of all traction or roller excavators which are not of the rotary type to block or bridge across the depressions and to lay heavy timbers on which to move the machine. Where the machine weighs 25 tons or more the expense of providing a solid foundation becomes quite great. In the rotary type of excavator the machine can be revolved and can build its own foundation of earth.

Drag-line excavators vary greatly in weight, not only with the capacity of the machine but with the manufacturer. Some of the five-eighths-yard stationary types weigh no more than 12 tons. There are a few standard makes of drag-line excavators which, although they may differ in details of construction, are operated in the same manner. They vary in weight from 25 tons to about 110 tons. It is especially noteworthy that in all makes the heavier machines are mounted on wooden rollers or on trucks to run on a track. Wheels and caterpillar traction are used only on the lighter machines. Although caterpillar tractors require no track, they have not given complete satisfaction when working under all the different conditions usually met with in operation. The wear on the chains is very great in sandy soil, and the expense of repairs and the time lost through breakdowns are likely to be considerable.

VARIATIONS IN ROTARY TYPE.

For the purpose of eliminating some of the weaknesses in the ordinary moving devices a novel design of walking scraper excavator of the rotary type has been put on the market. (See Pl. II.) Attached to the upper platform and extending through the machine in a direction at right angles to that of the boom is a heavy steel shaft, on each end of which is a wheel segment. The shaft also carries a large gear wheel, which meshes with a pinion on the loading-drum shaft of the main engine. Suspended from the middle arm of each segment by means of a carrying beam and chains is a long shoe which affords a bearing for the segment as it rotates and propels the machine forward. The machine can be made to move in any desired direction by first swinging the upper platform. The excavator is moved ahead 8 feet during each complete revolution of the segment. The great advantage of this type of machine, as well as of the excavator mounted on caterpillar tractors, is the reduction in the necessary working force from four to two men, the trackmen being unnecessary. It is claimed that five men can take this type of machine down in a week and erect it in about two weeks. The machine weighs about 60 tons and costs $7,000. Three cars are required for shipping it.

Another form of the rotary type is the so-called boom-guided bucket excavator. The entire machine rests on two steel rails spaced 12 feet apart and laid on short wooden ties. Either steam or gasoline may be used as power. The unique feature of this machine is the boom on which the scraper bucket travels. (Pl. III, fig. 1.) It is the purpose of this guide boom to overcome the difficulty of holding the ordinary bucket in place in passing from stiff to loose material.

The bucket, which is a rectangular steel box open at the end toward the machine, travels upon the guide boom on steel rollers. To fill, the bucket is first pulled outward by the back-haul cable, which leads from the bucket to the head of the main boom and back to the engine. The guide boom is then lowered and the bucket pulled toward the machine. The bucket is dumped by being pulled up on the vertical end of the guide boom, the boom having first been swung around to the location at which the material is to be deposited.

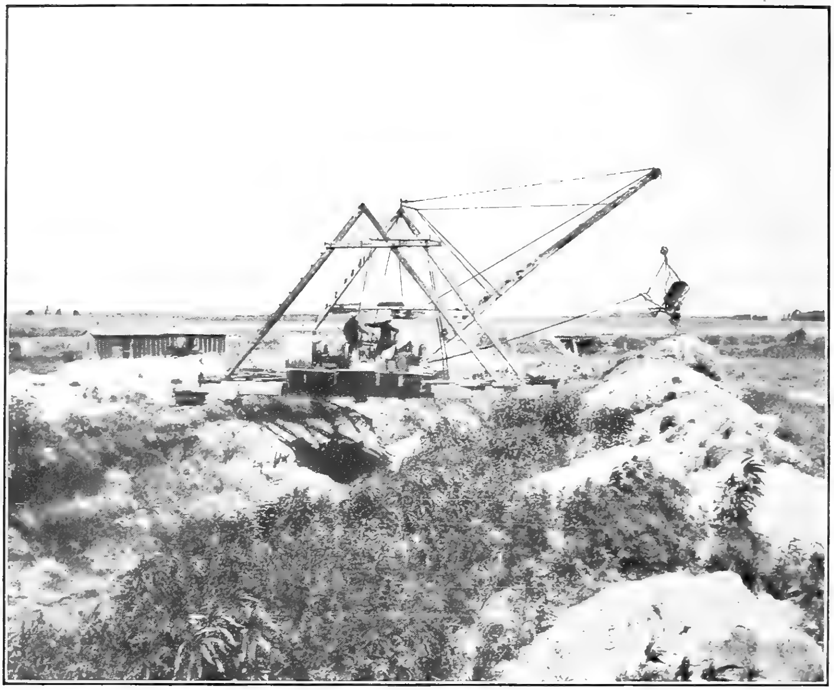
This machine is made with three different lengths of boom, a 30-foot adjustable boom which can be increased to 40 feet, a 40-foot, and a 65-foot boom. Buckets of $1\frac{1}{3}$, $1\frac{1}{2}$, and 2 cubic yards are used on these machines. It is claimed that 5 men can take down the

DI4118a

FIG. 1.—BUCKET AND GUIDE OF THE BOOM-GUIDED BUCKET EXCAVATOR.

D12393

FIG. 2.—A LIGHT STEEL SCRAPER EXCAVATOR MOUNTED UPON WHEELS.



DI4175a

FIG. 1.—A LIGHT WOODEN SCRAPER EXCAVATOR CLEANING A DITCH.

D12394

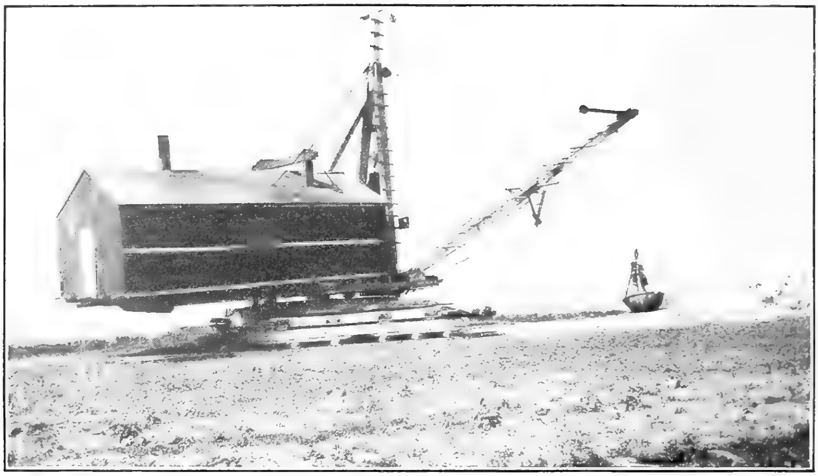
FIG. 2.—A SCRAPER EXCAVATOR WITH TWO BUCKETS AND MOUNTED UPON RUNNERS.

D12395

FIG. 1.—A 1-YARD DRY-LAND DIPPER EXCAVATOR MOUNTED UPON CATERPILLAR TRACTORS.

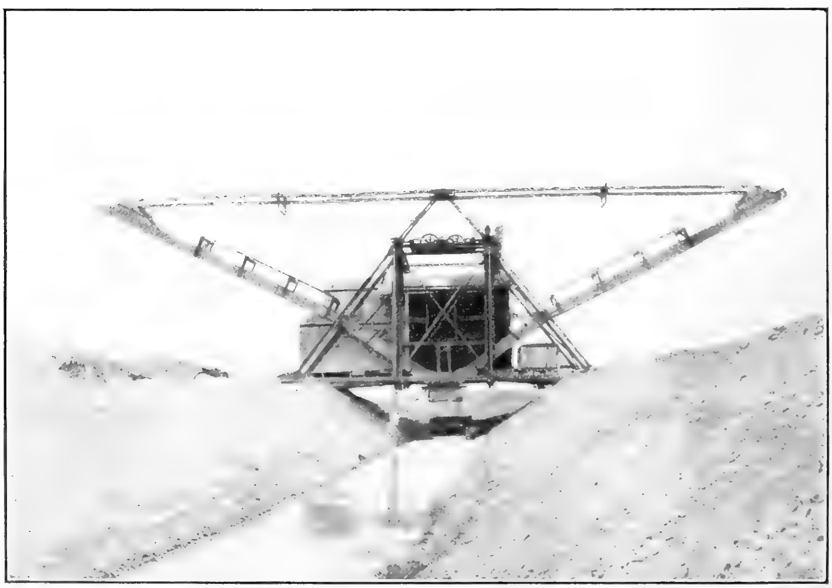
D12396

FIG. 2.—A 1-YARD DRY-LAND DIPPER EXCAVATOR MOUNTED UPON TRUCKS.



PR4177a

FIG. 1.—A DRY-LAND ORANGE-PEEL EXCAVATOR.



D12397

FIG. 2.—FRONT VIEW OF A TEMPLET EXCAVATOR.

machine of the smaller size in from 2 to 3 days and easily put it up in a week. It makes 13 loads on a wagon and can easily be loaded on a flat car.

COST OF ROTARY TYPE.

The cost of revolving drag-line excavators runs from about $6,000 to about $25,000. A steam-operated excavator equipped with a 40-foot boom and a 1¼-yard bucket costs about $6,500 if mounted on skids and rollers, and $10,000 if mounted on caterpillar traction. A steam-operated excavator equipped with a 60-foot boom and 2-yard bucket costs $9,000 if mounted on skids and rollers, and about $13,000 if mounted on caterpillar traction. If operated by internal combustion engines, this last-named machine would cost about $17,000. A steam excavator with a 125-foot boom costs approximately $27,000.

VARIATIONS IN STATIONARY TYPE.

A number of different forms of the stationary type of drag-line excavator are on the market. A light machine of this type has been put out recently which is being used quite extensively (Plate III, fig. 2). The machine is built entirely of steel. The main frame is 24 by 24 feet and can easily be made wider or narrower if desired. The platform is 12 by 30 feet. The frame is mounted on four steel wheels, each 5 feet high and 2 feet wide. The boom is 40 feet long and can be extended an additional 10 feet if it is desired to use the machine for tile trenching or lowering large tile into place. A 40-horsepower, 4-cycle gasoline engine is used for power. The bucket has a capacity of five-eighths cubic yard. The machine complete weighs 12 tons. When dismantled it can be loaded on one flat car, or if transported by team will make 7 wagon loads. One man is required to operate the machine and one man to handle the track in soft ground. From 20 to 25 gallons of gasoline are required per 10-hour day. The machine can be moved ahead without interrupting its operation by means of a cable attached to a "dead man" or to stakes. The large wheels will travel over reasonably firm ground without track and no trackman is therefore needed except in extremely soft ground or swamp. The machine costs approximately $4,500.

This same type of machine, made entirely of wood, is convenient for light work such as cleaning ditches, etc. Such a machine is illustrated in Plate IV, figure 1. It is equipped with two 12-horsepower, air-cooled gasoline engines, 50-foot boom, and ½ cubic yard bucket, and has been used in cleaning out old ditches in Iowa. The machine weighs about 12 tons and cost $3,000. Four men are required in using it, two operators and two trackmen. About 20 gallons of gasoline are required per 10-hour day. Four men can set such a machine up in 3 days and can take it down in 2 days. The maximum width of ditch a machine of the above size can dig is 50 feet and the greatest depth is 22 feet. It has excavated 500 cubic yards in 10 hours. The machine is supported on 4 wheels, and is moved on the work in advance of the excavation by cable and "dead man."

Another drag-line machine of the stationary type has been designed to meet the demand for a light excavator that can be economically and quickly moved across country from one job to another. The power consists simply of a steam or oil traction engine which forms the rear of the machine as shown in figure 1. The front end is carried on two wide wheels. It is claimed that this excavator can be moved over ordinary country roads, or even across fields, at the speed of an ordinary large traction engine, and that it can be quickly taken apart and reassembled if shipment is desired. For work on soft ground a heavy timber pad is provided for each wheel. These are shifted by engine

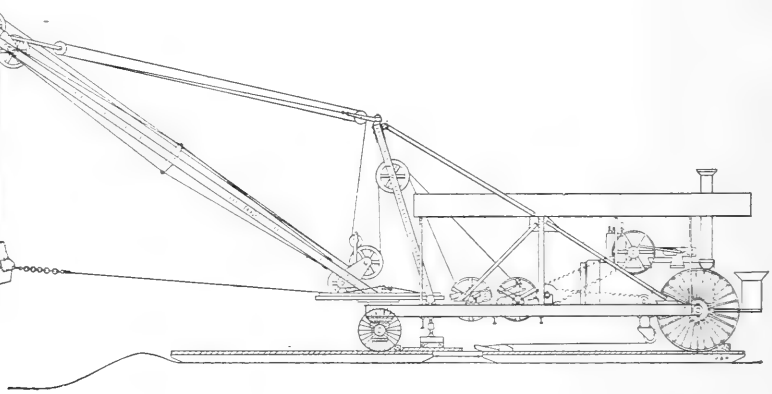


FIG. 1.—Drag-line scraper excavator of the stationary type.

power; in doing this one side of the machine at a time is raised on power jacks.

A drag-line machine with two buckets has been used to some extent in the excavation of drainage channels. This machine, illustrated in Plate IV, figure 2, is mounted either on runners or on caterpillar tractors. The two booms, which are separated at the foot according to the width of the ditch to be cut, swing from the center of the ditch outward. The operations are so timed that one bucket is being emptied while the other is being filled. This feature greatly increases the output of the machine. The excavator can be dismantled for shipping in about 2 weeks and can be assembled in about 1 month by a crew of 5 men. Under favorable conditions this machine has excavated 1,500 cubic yards in 15 hours. Such a machine, equipped with 42-foot booms, can dig a ditch with a 46-foot top, 25-foot bottom, and 12-foot depth.

COST OF OPERATION.

A drag-line excavator of the rotary type, having a 2-yard scraper bucket and a 60-foot boom, was used in the construction of some drainage ditches in southern Texas. It was built mostly of wood and moved on rollers. Power was derived from an 80-horsepower internal-combustion engine, burning oil. The cost of the excavator, ready to operate, was $12,000. It was operated about 10 months in two daily shifts of 10 hours each, a shift consisting of 10 men. The actual working time was not recorded. The ditch ranged from 4 to 22 feet in bottom width, from 3 to 12 feet in depth, and had 1 to 1 side slopes. The soil varied from a stiff, heavy clay to a fine sand. The excavation amounted to 230,000 cubic yards; the cost was as follows:

Operating expenses	$22, 313. 36
Miscellaneous expenses	374. 70
Interest and depreciation	4, 100. 00
	26, 788. 06

Cost per cubic yard, $0.1164.

On another drainage project in southern Texas, a 2-yard rotary excavator was used. The machine was of steel throughout, had a 60-foot boom, and was mounted on caterpillar traction. The crew consisted of a foreman, operator, engineman, oiler, and two laborers. The machine was operated by a 110-horsepower internal-combustion engine, with oil as fuel. The total cost of the machine was about $17,500. The cost of erection was $509. During the four months of operation two 10-hour shifts were run. The ditches ranged from 4 to 22 feet in bottom width and from 3 to 12 feet in depth, with 1 to 1 side slopes and 8-foot berms. The material excavated was a stiff, heavy clay. The excavation amounted to 91,400 cubic yards; the cost was as follows:

Operating expenses	$8, 873. 82
Miscellaneous	371. 00
Interest and depreciation	2, 391. 00
	11, 635. 82

Cost per cubic yard, $0.1273.

In the same general locality as the last example a 1½-yard rotary drag-line excavator, operated by a 50-horsepower internal-combustion engine and mounted on caterpillar traction, was used in the construction of some ditches in soil ranging from stiff, heavy clay to fine sand. The ditches were of the same dimensions as in the foregoing example. The machine was rebuilt from an old dipper dredge at a cost of about $1,200. It was operated in two daily shifts of 10 hours each. The crew for each shift consisted of from 5 to 6 men. During the five months of operation the machine moved 59,014 cubic yards at an expense, exclusive of interest and depreciation, of $8,921, or $0.1512 per cubic yard.

A rotary drag-line excavator with a $2\frac{1}{4}$-yard bucket and 65-foot boom, mounted on skids and rollers, was used in the excavation of 222,500 cubic yards in South Dakota. The power was obtained from a 50-horsepower internal-combustion engine, using gasoline. The cost of the machine, complete, was $10,500. The total time of construction was 148 working days, or approximately 6 months, of which 23 days were occupied in making repairs. Two shifts of 11 hours each were run. The soil was a loam underlain by clay. The crew and rates per month were as follows: One superintendent, $125; 2 cranemen, at $100; 4 trackmen, at $50; 1 teamster, $45; 1 cook, $40. The operating expenses were as follows:

Gasoline, 15,444 gallons, at $0.124	$1,915.05
Labor	3,060.00
Subsistence	561.81
Cables	978.87
Repairs and renewals	845.93
Miscellaneous	2,078.72
Interest and depreciation	2,152.50
	11,592.88

Cost per cubic yard, $0.0521.

The following costs were secured on the operation of a rotary drag-line excavator with an 85-foot boom, 2-yard bucket, and a 50-horsepower engine. The work was done on the New York State Barge Canal. The machine weighed 147 tons and cost $10,000. It excavated earth 90 feet from center on one side and deposited it 100 feet from center on the other. It dug a channel 25 feet deep and deposited the material on waste bank 15 to 25 feet high. The material was a stiff clay, with few stumps or bowlders. The following is a condensed cost record for 5 months' work:

Month.	Total expense for month.	Yards excavated during month.	Average cost per yard.
April	$1,088.21	5,205	$0.209
May	1,041.53	18,365	.0568
June	1,152.04	25,333	.0455
July	1,317.61	33,055	.0399
August	1,535.36	47,363	.0324

Average cost per yard for 5 months, including all charges, $0.0474.

In May, items of cost were as follows:

Engineer, at $90 per month	$90.00
Engineer, at $95 per month	84.04
Fireman, pumpmen, watchmen, etc., at $1.75 per day	363.00
Coal, at $3 per ton	147.00
Repairs, including labor and material	15.82
Interest and depreciation	341.67
Total	1,041.53

SELECTION OF SCRAPER EXCAVATOR.

In selecting a scraper excavator the purchaser, in addition to choosing the most desirable kind of power and the best means of moving over the ground in his particular case, must determine the length of boom best suited to his needs.

Figure 2 is a diagram showing the relation between the length and angle of elevation of boom and the effective reach of machine. In this diagram all distances are referred to the heel of the boom. If it is desired to refer horizontal distances to the center of the machine, the correction A must of course be added; this distance varies with the different makes of machine. The distance, B, of the heel of the boom above the ground, likewise varies slightly in different machines.

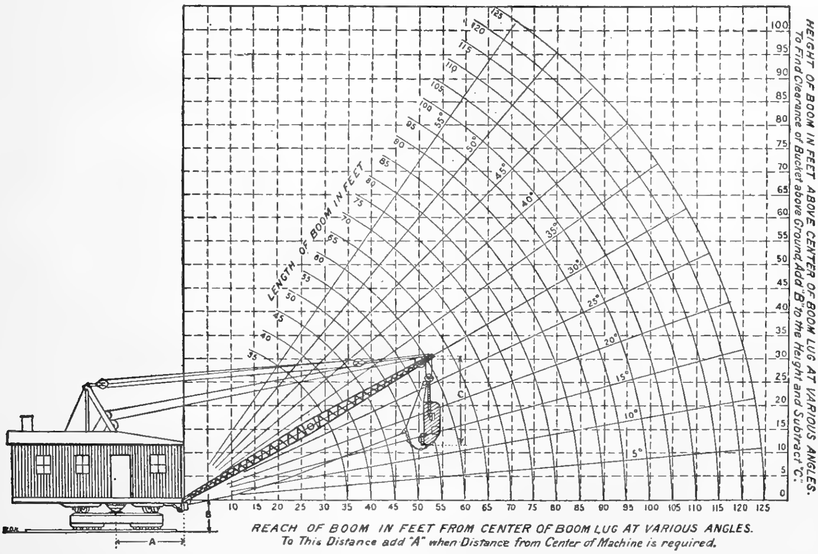


FIG. 2.—Diagram of scraper excavator, showing relation between the length and elevation of boom and the effective reach of machine.

To determine the maximum clearance of the bucket above the ground for different lengths and positions of boom, the distance B must be added to the vertical heights given on the right-hand margin of the diagram; and from this sum must be subtracted the distance C, which will depend entirely upon the type of bucket used. Thus, for a 70-foot boom elevated at an angle of 35°, the horizontal distance from the center of machine to the bucket would be 57 + A; and at that position of the boom the bucket would just clear a waste bank of a height 40 + B − C.

THE DRY-LAND DIPPER EXCAVATOR.

Excavating machines employing the same digging principle as used on the floating dipper dredge, but moving on land, either over or in the ditch, are used to a considerable extent in drainage work. A common form of this type straddles the ditch on cross-beams. The straddle ditchers generally work upstream as do all dry-land excavators.

A machine of this type often used is illustrated in Plate V, figure 1. It has a 30-foot boom and a 1-yard dipper. The steam power used is obtained through a 2-cylinder, 35-horsepower engine and a vertical boiler. The machine rests on a platform which is mounted on two steel beams, each 29 feet long, that straddle the ditch. It can be mounted on either caterpillar tractors or wheeled trucks. In the latter case, each end of the two beams is supported on a 2-wheeled oscillating truck, the wheels being 2 feet high and 18 inches wide. They run on a wooden track 6 inches thick and 3 feet wide, which is built in 6 sections each 20 feet long. One section of the track on each side is always unoccupied and these are lifted ahead by means of cranes operated by power derived from the engines. This track will support the machine in the softest ground. The excavator will dig 12 feet deep and 22 feet wide on firm ground; with an extension to the dipper handle it can dig 18 feet deep. It will deposit the dirt on either side at a distance of 32 feet from the center of the ditch. The dipper will swing over a bank 14 feet high. Where track is used the machine is pulled ahead by a cable from the engine which hooks to the track on both sides; this is done without interrupting the work of excavating. If desired, caterpillar tractors are furnished instead of the wheeled trucks. The front tractors are 4 feet wide by 11 feet long, and the rear tractors are 4 feet wide by 7½ feet long. This excavator has been known to dig as high as 1,500 cubic yards in 10 hours in especially favorable material. It has dug through 12 inches of frost. From 7 to 8 men can set up and take down the machine in from 5 to 8 days.

Another machine of this type is illustrated in Plate V, figure 2. The excavator is made in various sizes; that most commonly used has a 38-foot boom and a 1-yard dipper. Power is supplied by an internal-combustion engine of 25 or 40 horsepower which burns kerosene, gasoline, or distillate oil. The machine rests on a platform which is mounted on two steel beams, whose standard span is 32 feet. Extension axles are provided which permit of a maximum increase of 3 feet in the span. The front axle is mounted on a two-wheeled swiveling truck with cast-steel double-flange wheels. The rear end is carried by two heavy, wide-faced, double-flange steel wheels set loosely on the axle. The shipping weight of this size of dredge, including engine, dipper, and machinery, is approximately 38,000 pounds.

Perhaps the cheapest straddle-ditch excavator of the dipper type that is in use is a homemade one which has been used to some extent on small ditches in Iowa. The machine is of the revolving type. It is equipped with a three-fourths-yard dipper and a 28-foot boom. The power is derived from a 6-horsepower gasoline hoisting engine geared to three hoisting drums, one of which hoists the end of the dipper, one hoists the boom, and one pulls the machine ahead. The machinery is mounted on a platform which revolves upon a turntable supported on two wooden beams which straddle the ditch. The beams rest on wooden wheels, the entire span being 22 feet. The dipper handle, instead of moving forward and backward in the boom, is pivoted. The entire machine weighs only about 17,000 pounds and costs about $1,200.

This excavator has dug as high as 400 cubic yards a day, but averages about 200 cubic yards. It can excavate a ditch with a 20-foot top and can dig 13 feet deep, but 6 or 7 feet is the best working depth. Two men can erect the machine in 2½ days and dismantle it in one-half day; it makes about 7 wagon loads. The hoisting apparatus, which is the heaviest part of the machine, weighs 4,100 pounds. The excavator is moved ahead by means of a "dead man" and cable, and can be moved across country at a speed of about 1 mile per day. The machine can take out 5 shovel-loads in 2 minutes, and has dug through 6 inches of frost. Only 2 men are required to operate it—1 operator and 1 trackman.

A ditch constructed by this machine in Iowa had an 18-foot top, 4-foot bottom, and 6½-foot depth. From 8 to 10 gallons of gasoline, costing 16½ cents at the works, were used per day. The material, which was a loam underlain by a stiff gravelly subsoil, was excavated at the rate of about 200 cubic yards in 10 hours. The cost of operation per shift was as follows:

One operator	$4.00
One trackman	2.00
Ten gallons gasoline, at $0.16½	1.65
	7.65

The cost per cubic yard, exclusive of interest and depreciation, was about 3.8 cents. The contract price on 5,000 cubic yards was 12 cents.

Such a machine as this would be well adapted to digging the small ditches in the South that are almost universally put in by hand at a cost of about 25 cents per cubic yard. Even in ground covered with stumps, by using plenty of dynamite this type of excavator could be used to advantage in reducing the cost of small ditches.

In general, it may be said that the dry-land dipper dredge, though applicable to certain conditions, has no extensive use in drainage work, as excavation that is suitable to this machine can usually be handled to better advantage by the drag-line scraper excavator.

THE DRY-LAND GRAB-BUCKET EXCAVATOR.

Dry-land grab-bucket excavators of both the rotary and stationary types are in quite extensive use. A machine of the former type, having an orange-peel bucket, is illustrated in Plate VI, figure 1. The excavator either moves on wooden rollers resting on planks, or is mounted on four trucks which move on a track built in sections so that it can be taken up in front and relaid behind as the work progresses. In the revolving type this shifting of track is ordinarily done by the machine itself.

A nonrevolving, orange-peel excavator with a 1-yard bucket was used in building a levee 10 miles in length and inclosing about 2,500 acres of land. The excavator was mounted on four 4-wheel trucks that ran on 4 lines of track. The machinery consisted of a 60-horsepower boiler and a 30-horsepower double-cylinder hoisting engine. The boom had a swing of 75 feet and a rise of 20 feet. The machine weighed about 50 tons and cost about $4,000. The levee averaged 7 feet high and 6 feet wide on top; it had 2 to 1 slopes on both sides. The material excavated amounted to about 270,000 cubic yards. The cost of labor, fuel, oil, and repairs amounted to $19,989, making the cost of the levee about 7.4 cents per cubic yard, exclusive of interest and depreciation.

THE TEMPLET EXCAVATOR.

All of the machines hitherto discussed cut ditches with more or less rough and irregular slopes and bottoms. Although these features are to a certain extent under the control of the operator, the completed work at best is not equal in appearance nor in hydraulic efficiency to the results obtained by the templet excavators. In the latter type of machine, excavation is accomplished by one or more buckets attached to an endless chain which travels over a guide frame or templet and cuts successive slices of material from the perimeter of the ditch. Although the templet machine cuts a superior ditch where soil conditions are favorable (see Plate VII, figure 2), it can not, in its present development, cope with stumps, rocks, or extremely hard earth.

A form of templet excavator is shown in Plate VI, figure 2. It has a single bucket which moves along a guide frame shaped to the desired cross-section of the ditch. The entire machine may be mounted on caterpillar tractors or on wheels which run on a wooden track.

The ditch section is dug by the excavation from its perimeter of thin layers of material which the bucket carries to the outer ends of the frame and dumps on the waste bank. This machine is made in two sizes, for the construction of ditches with narrow and wide bottoms, respectively. The narrow-templet machine will dig ditches ranging in size from 3 feet wide and 2½ feet deep up to 19 feet wide and 8 feet deep; while the wide-templet machine will construct channels varying in size from 6 feet wide and 6 feet 3 inches deep, to 32½ feet wide and 12 feet deep.

The excavator is operated either by steam or gas engine. A 25 to 40 horsepower steam plant is necessary, depending on the size of the excavator; or, if an internal-combustion engine is used, from 50 to 80 horsepower is required. The bucket varies in size from ½ cubic yard to 2 cubic yards. An operator and 1 assistant are required to operate the machine.

COST OF OPERATION.

A single-bucket templet excavator was used in southern Louisiana on the construction of 7,825 feet of ditch having a 24-foot bottom width and ranging in depth from 3.5 to 7 feet. The side slopes were 1 to 1, and the width of berm was 15 feet. The total excavation was 43,128 cubic yards. The total cost of this machine on the work was $8,506.22. The soil was a yellow clay with a few spots of gravelly clay, and the top soil was baked very hard. No special difficulties were encountered except that considerable cribbing was necessary to level up the track supporting the excavator when crossing natural water courses; except for these streams the ground was level. Some trouble was also experienced with the traction device, due to the fact that the ditch was larger than that for which the machine was designed. The actual number of working days was 128, 73 days of which were spent in actual digging. The cost of operation per day was as follows: One operator, $3.85; one fireman, $2.28; three deck hands, $6.27; one team and teamster, $5.40. The total cost per day was $17.80. The average daily excavation for the number of days worked was 337 cubic yards. The total cost of operation for 5 months was $3,500.58. Interest and depreciation in that time, at 41 per cent per annum, would amount to $1,452.82, making the total cost $4,953.40 and the cost per cubic yard $0.1149. Table 1 is an itemized statement of cost for the entire work.

TABLE 1.—*Cost of operation of single-bucket templet excavator on a ditch in Southern Louisiana.*

Month.	Labor.		Material.		Fuel.	Total cost.
	Operation.	Repairs.	Operation.	Repairs.		
	Dollars.	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
February	170.00	26.00	45.00	20.00	55.39	316.39
March	439.75	48.90	141.92	52.63	158.50	841.70
April	306.59	116.31	122.05	91.34	100.00	736.29
May	499.63	46.80	77.69	5.41	156.92	786.45
June	469.27	56.47	109.37	53.61	131.03	819.75
Total	1,885.24	294.48	496.03	222.99	601.84	3,500.58

TABLE 1.—*Cost of operation of single-bucket templet excavator on a ditch in Southern Louisiana*—Continued.

Month.	Excavation.	Cost per cubic yard.	Distance excavated.	Total number days worked.	Actual number days digging.	Average length dug per day.	Maximum length dug per day.	Average depth.	Maximum depth.
	Cubic yards.	*Cents.*	*Feet.*			*Feet.*	*Feet.*	*Feet.*	*Feet.*
February	4,175.9	0.076	1,115	16	9.45	120.5	195	3.63	5.30
March	10,559.0	.080	1,785	30	18.7	95.4	140	5.62	7.00
April	7,303.0	.101	1,200	26	10.8	111.1	114	5.57	6.70
May	10,151.2	.077	1,850	29	18.1	102.3	120	5.10	5.80
June	10,938.5	.075	1,875	27	16.3	115.03	135	5.38	6.10
Total or av'g	43,127.6	.081	7,825	128	73.35	106.60	195	5.06	7.00

THE WHEEL TYPE OF EXCAVATOR.

The wheel excavator consists of a steel frame mounted on wheels, which supports on the front end an engine and boiler and on the rear end a pivoted steel framework holding the digging wheel, as shown in Plate VII, figure 1. This excavating wheel revolves upon antifriction wheels placed just outside the rim of the wheel. The excavating scoops or buckets are placed on the circumference of this wheel. The front of each scoop is provided with a cutting edge, which slices a thin layer of earth from the trench as the wheel rotates. When the bucket reaches the top of the wheel, the earth falls onto a belt conveyor, which deposits it on the waste bank. The machine can be mounted on caterpillar tractors for use in wet soil. It is built in several sizes, so that ditches with top widths of from 2½ to 12 feet and with smooth side slopes can be dug. The cost of the excavator varies from \$4,000 to \$12,000, according to the size of ditch it is desired to dig.

There is a wheel type of trench excavator so designed that by adding side knives sloping sides can be dug. This machine is illustrated in Plate VII, figure 2. A series of buckets attached to two parallel chains travel over the circumference of a wheel mounted on a frame, which is supported by a central shaft about which the wheel revolves. The cutting knives slice the earth from the sides of the ditch, the dirt falling into the path of the buckets. The excavator is made in two sizes. The smaller size will dig 5 feet deep, 90 inches wide, and any side slope not flatter than 1 to 1. The larger size will dig 6 feet deep and 10 feet wide. The machine may be mounted on caterpillar tractors. For the small size 4 by 6 foot tractors are used, while the large machine requires 4½ by 11 foot tractors. Either steam or gasoline power is furnished. This wheel excavator is suitable for the construction of small open ditches. It works to the best advantage in a soft, wet soil; under these conditions its average daily output is about 300 cubic yards.

Experience has shown that it is a mistake for a maker to attempt to build one machine of this type that is suitable for all classes of soil. Attempts to do this have, up to this time, met with doubtful success.

COST OF OPERATION.

Two machines of the wheel type designed to cut a ditch 4 feet deep, 4 feet wide at the top, and 2 feet wide at the bottom, were used on the excavation of some ditches in one of the Gulf States. Each machine was driven by a 28-horsepower gasoline engine. The digging wheel was 15 feet in diameter and the 2 apron tractors each 5 feet by 12 feet. The weight of each excavator was about 30 tons. The first cost of the machine was $5,500 and freight to the point of use was $338.36, making the total cost of each machine $5,838.36. The soil was a hard, yellow, sandy clay overlain by a turfy muck, varying in depth up to 2½ feet. The turf was easily cut, but the hard clay caused excessive wearing on the bearings. A large part of the work was done when water was from 2 to 3 feet deep on the land. The total length of the ditches dug was 165 miles, the average length of ditch being 2,475 feet. The average depth of digging was about 4 feet, with a 4-foot top and 2-foot bottom. The average distance dug per shift of 10 hours of actual running time was 2,250 feet; the maximum distance dug in 10 hours was 6,600 feet. The average yardages per month for the two machines were 13,245 and 13,180 cubic yards, respectively. The average daily outputs on the basis of the actual running time were 1,000 and 1,126 cubic yards, respectively. A part of the time the first machine ran a double shift, which accounts for the higher monthly and less daily average. It required 13 months to complete the work, the actual time of operation being about half this. On account of the excessive wearing on the bearings, caused by the heavy sandy clay, it was necessary to make frequent stops for rebuilding the machines, which operation occupied an average of nearly two weeks. The total excavation was 317,162 cubic yards.

The daily operating expense per 10-hour shift for each machine was about as follows:

	Per day.
One operator, at $100 per month	$4.00
One assistant	2.00
50 gallons gasoline, at 16 cents	8.00
Repairs	6.00
Other charges	12.00
	32.00

The itemized cost for operation for the entire work was as follows:

Labor	$5,172.11
Interest, discount, and exchange	202.05
Maintenance and repairs	2,860.08
General expense	273.10
Management expense	1,600.00
Provisions and cooking (cook's wages)	2,245.91

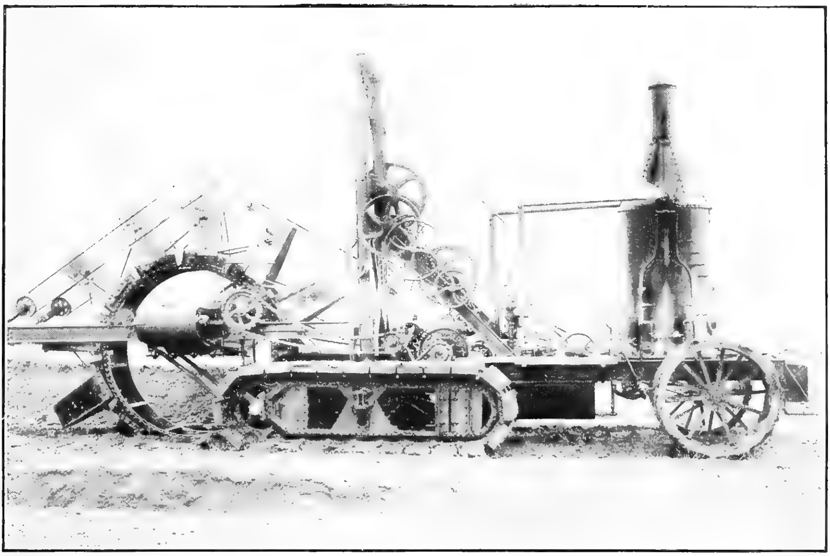
Freight and express	$75.74
Towing	458.19
Gasoline	1,792.22
Other oil	281.49
Teams and livery	932.11
Telephone and telegraph	25.29
Motor-boat operation	540.96
Interest and depreciation on machinery	5,185.00
	21,644.25

Cost per cubic yard, $0.0682.

	Machine No. 1.	Machine No. 2.
Machine running	$917.97	$1,509.66
Machine repairing	1,431.37	771.96
Machine moving	105.20	88.51
Machine bogged	156.90	190.54
Total	2,611.44	2,560.67

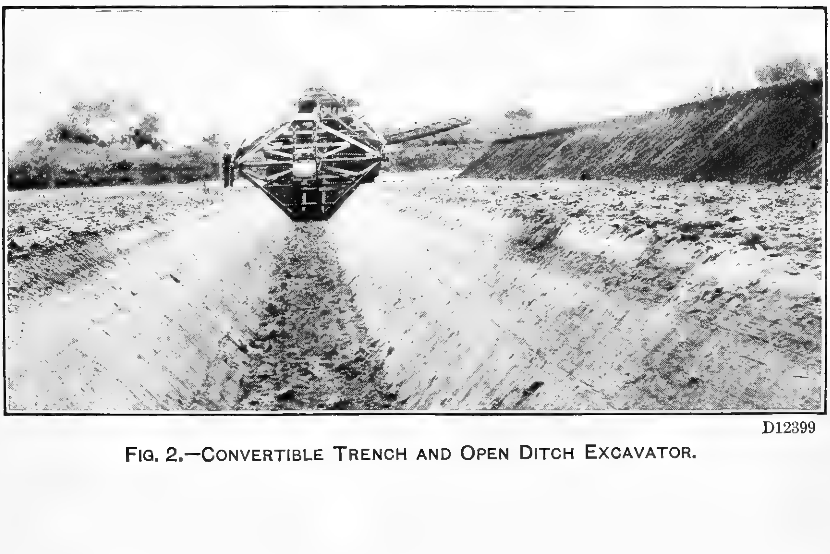
The excessive cost of labor given for the machines when bogged was due to the frequent crossings of a wide, muck-filled bayou which ran the entire length of the district. This bayou was about 1,500 feet wide; the muck ranged from 5 to 15 feet deep and was very soft. No tree roots, submerged timber, or stumps were encountered. The work covered an area of about 7,000 acres, approximately square, which was traversed by parallel canals every half mile. The ditches cut by the excavators were at right angles to these canals and were spaced 330 feet apart. It was thus necessary to turn the machine around and run it light 330 feet for each half mile of ditch cut. The item "moving" is for taking the machine across the canals and for moving from one part of the district to another; it does not refer to the moving between adjacent ditches.

On a project in southern Louisiana a wheel excavator, cutting a ditch 4½ feet deep with a top width of 4½ feet and a bottom width of about 20 inches, was used. The machine worked on comparatively solid ground. Power was supplied by a 28-horsepower gasoline engine. The first cost was $4,000, and freight charges from factory to works were $350. After the machine had been operated for a short time it became apparent that the excavating wheel was far too light and a new wheel was substituted. The soil was a silt loam, firm and uniform but not tenacious. No special difficulties due to soil conditions were encountered in this work. The chief obstacles to rapid progress were at first the weakness of the light excavating wheel, and afterwards the extra-heavy excavating wheel which unbalanced the machine. The tractors were larger than necessary and often broke down when turning on the hard ground. At the time the following cost records terminated, the work had been carried on intermittently for about 18 months; about one-half this time was occupied in repairs. During this time the machine dug 117,000 feet of ditch 4½ feet deep, 45,500 feet 3½ feet deep, and 9,250 feet twice over, the



D12398

FIG. 1.—A TRACTION DITCHER OF THE WHEEL TYPE.



D12399

FIG. 2.—CONVERTIBLE TRENCH AND OPEN DITCH EXCAVATOR.

D12400

FIG. 1.—DREDGE AT WORK AND COMPLETED LEVEE.

D12401

FIG. 2.—CONSTRUCTION OF LEVEE SHOWING SLOPE BOARDS.

LEVEE CONSTRUCTION BY HYDRAULIC-FILL METHOD.

machine making two $4\frac{1}{2}$-foot cuts side by side. The average length of ditch cut per day was 800 feet, while the maximum was 1,950 feet. The daily cost of operation was as follows:

Labor	$5.50
Fuel	4.20
Incidentals	.50
Repairs	2.40
	12.60

The average excavation per day was 410 cubic yards, based on the average of 800 feet of ditch, $4\frac{1}{2}$ feet deep, $4\frac{1}{2}$ feet wide at the top, and 20 inches wide at the bottom. The machine excavated 82,330 cubic yards in 18 months at the following itemized cost:

Gasoline based on 215 actual days' operation (estimated)	$903.00
Repairs, actual cost	860.00
Incidentals, at 50 cents per day	120.25
Labor of foreman, 18 months, at $75 per month	1,350.00
Other labor, two men, $2.50 per day for 250 days	625.00
Interest and depreciation	2,675.25
Total	6,533.50

Cost per cubic yard, $0.0793.

THE HYDRAULIC DREDGE.

The hydraulic dredge has little application in the construction of ditches for drainage purposes, due to the fact that nearly all the drainage ditches are of too small a cross section to be economically dug by this method. This type of dredge probably is, however, the most economical machine existing for excavating very large channels.

The essential parts of the hydraulic dredge are a centrifugal pump and the power to drive it, the whole mounted on a barge. The suction pipe is attached to the pump by a movable joint so that the suction end can be raised or lowered. The material, mixed with water, is drawn through the suction pipe and discharged where desired through a line of pipe sometimes several thousand feet long. Coarse sand and gravel, muck, and silt are easily handled in this way, and by the use of a rotary cutter on the end of the suction pipe, comparatively hard clay can be removed. The machine does not work well, however, where there are stumps, logs, stones, or other such obstructions.

Dredges of this type are suitable for digging ditches 800 or more square feet in cross section, for building levees under favorable conditions, and especially for building up tidal flats and low lands.

COST OF OPERATION.

The following table indicates the cost of operating a hydraulic suction dredge on the New York Barge Canal in 1908. The dredge in question is of modern construction, has a 20-inch discharge pipe, and cost $115,000. Once during this season the dredge was sunk to the bottom of the canal; otherwise, the work was done under favorable conditions and the excavation made was representative of the capacity of the machine in ordinary clay soil.

Cost of excavation by hydraulic suction dredge on the New York Barge Canal for the season 1908.

Month.	Labor.	Plant.[1]	Material.	Total for month.	Yards excavated.
	Dollars.	*Dollars.*	*Dollars.*	*Dollars.*	
April	3,670.95	408.30	1,900.62	5,979.87	120,673
May	5,169.29	1,367.60	2,558.88	9,095.77	204,838
June	5,615.75	1,677.85	2,263.16	9,556.76	203,474
July	5,835.14	1,735.50	2,446.45	10,017.09	207,520
August	5,985.87	1,631.15	2,320.92	9,937.94	174,395
September	4,993.11	1,692.85	2,430.05	9,116.01	231,473
October	4,834.14	1,791.15	2,573.50	9,198.79	214,438

[1] Interest and depreciation at 15 per cent per annum.

Average cost for the season, $0.0464 per yard.

USE IN CONSTRUCTION OF LEVEES.

It formerly was considered that the hydraulic dredge was not applicable to levee construction for the reason that the large amount of water pumped made it difficult to keep the solid material from spreading over a wider base than desired for the levee. It was generally thought necessary to build ridges to form the toes of the embankment, with earth dry enough to hold the wet material within the desired limits until the solid matter had been deposited; in this manner one layer was added to another until the desired height of levee was reached. The need of this dry material is avoided by methods now in use by which the entire section of the levee is built in one operation.

Plate VIII and Plate IX, figure 1, illustrate the method of forming the desired slopes by means of steel boards about 18 inches wide and 10 feet long, made of No. 14-gauge steel with angle-iron top. These boards are not too large nor too heavy to be easily moved by one man. In Plate VIII, figure 2, the slope boards are easily seen; they are placed at the intersection of the side slope with the natural slope of the end of the fill under construction. Several men equipped with shovels are necessary to distribute the material evenly and to move the slope boards ahead as the levee is built up.

On a section of levee built along the Mississippi River near Burlington, Iowa, a hydraulic dredge consisting of a hull 24 by 80 by 4½ feet, upon which was mounted a centrifugal pump having a 12-inch suction pipe, a 14-inch discharge pipe, a 200-horsepower engine, and a boiler nominally rated at 150 horsepower, was used for the construction. The discharge pipe was carried from the dredge to the top of the levee by small towers mounted on 14 by 40-foot barges. A strip about 30 feet wide along the center of the site of the levee was grubbed and ploughed. No muck ditch was prepared. The levee was about 14 feet high with an 8-foot crown and 3 to 1 slopes on both sides. The number of men usually employed was about 14, and the fuel used was about 5 tons of good coal in each shift. Two 11-hour shifts built 100 linear feet of completed levee, or 2,700 cubic yards. A dredge of this type costs approximately $15,000, not including the discharge pipe, the barges, and other necessary appurtenances which will add about $5,000, making the total first cost about $20,000 for a plant to build levees by this method.

With hydraulic-fill levees a wide foreshore can be left. There are no borrow pits to aid in probable seepage and consequent failure of the levee. Any side slope wanted for a levee can be built. There is no shrinkage after the embankment is first completed, for the material is thoroughly compacted. The fine material is deposited in the base of the levee where it is most needed to prevent seepage. By using the hydraulic-fill method, a levee can be built across an old bayou or lagoon with as little trouble as on dry ground, which can be done by few machines. Wet, soggy ground gives no trouble in construction. Hydraulic-fill levees, being composed mostly of sand, are proof against damage by burrowing animals.

On the other hand, a 20-foot head with about 600 to 800 feet of discharge pipe are the maximum conditions under which a plant developing only 200 horsepower can operate; greater heights and distances must be overcome by a corresponding increase of power equipment. The dredge must always be in about 8 feet of water to prevent air from being drawn into the suction pipe. It would hardly pay to put such an outfit on a project of less than 250,000 cubic yards.

It has been observed in hydraulic fills made with clay that the tendency to settle is not so marked as when sand alone or sand mixed with some silt is pumped. The tendency of the sand to settle in the bottom of the discharge pipe permits the building of levees having any slope between the natural slope assumed by moist sand and that of a semifluid. By using the slope boards, however, a greater range of side slopes can be had.

MACHINES FOR CLEANING OLD DITCHES.

A floating dredge as a rule is unsuited to cleaning old ditches unless the amount of material to be excavated is large. It is also impracticable to dam up the channel on account of possible damages to the landowners. Moreover, all bridges must be removed if a machine of this kind is used.

A type of the stationary scraper excavator which straddles the ditch has been used quite successfully on the smaller ditches. On large ditches the top width is too great to permit the use of a machine of this type. The scraper machine of the rotary type, operating from the top of one waste bank, has also been used for cleaning out old ditches. With this kind of machine the banks of the ditch can be trimmed. However, the machine must first level down the old waste bank sufficiently for it to travel over. An orange-peel bucket, instead of the scraper bucket, has also been used on the drag-line machine for cleaning ditches. With the drag-line excavator it is unnecessary to remove bridges, which item effects a considerable saving in cost of cleaning ditches on a large project. The rotary type of scraper excavator is probably the most efficient machine for cleaning ditches.

A small centrifugal pump operated by gasoline power and mounted on a small hull has been used in cleaning out some ditches in Iowa. This device is illustrated in Plate IX, figure 2. The pump, which has a 5-inch suction pipe and two 5-inch discharge pipes, is operated by a 48-horsepower internal-combustion engine which starts on motor spirits and runs on kerosene. The whole equipment was mounted on a hull 28 feet long, 5 feet wide at the bottom, 10 feet wide at the top, and about 4½ feet deep. Immediately in front of the hull were placed five cutter wheels, each 3 feet in diameter and weighing 100 pounds. These cutter wheels were operated by power obtained from the engine. The end of the suction pipe was 5 feet long and 2 inches wide and was placed about 2 feet behind the cutter wheels. Half of the material was discharged on each side of the ditch, beyond the waste bank. The dredge cleaned from 250 to 300 feet of ditch in a day of 10 hours. The excavation amounted to about 1½ cubic yards of earth for every linear foot of ditch. Three men were required to operate the dredge. By taking down one discharge pipe and turning the other lengthwise of the ditch the dredge could easily pass under the bridges. Four men could dismantle the dredge in 2 days and set it up in 5 days. The complete cost of the plant was $3,000. For removing sand and silt from ditches this type of machine is excellent. The dredge works downstream and must have considerable water. The average cost of operation per day was as follows:

One engineer	$3.00
One assistant	2.50
One helper	2.00
Twenty gallons kerosene, at 10 cents	2.00
Total cost per day	9.50

Based on 200 feet of ditch cleaned, the excavation per day would be 300 cubic yards, and cost per cubic yard about 3 cents, exclusive of interest and depreciation. The actual unit cost for the whole job, however, would run very much higher than this, due to delays and repairs.

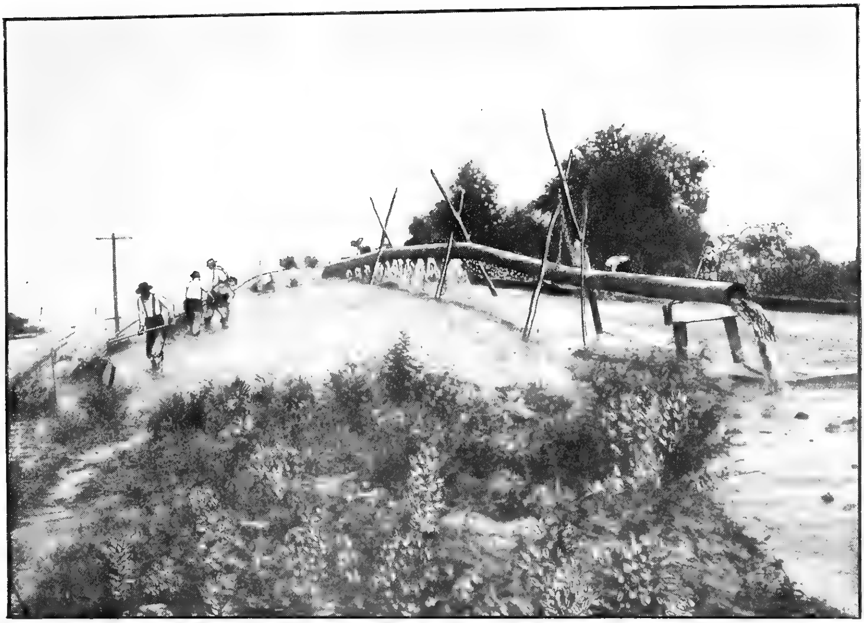


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FIG. 1.—HYDRAULIC-FILL LEVEE CONSTRUCTION SHOWING METHOD OF FORMING LEVEE SLOPES.

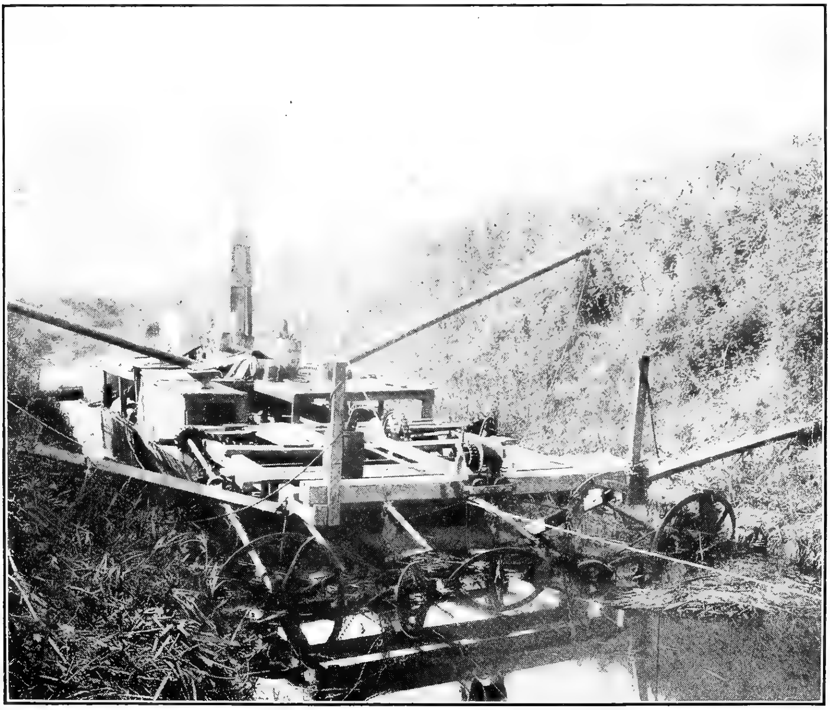

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FIG. 2.—SMALL HYDRAULIC DREDGE USED FOR CLEANING DITCHES.

SUMMARY.

Power machinery is now available which will construct outlet drainage ditches of all sizes, and under all conditions of soil and water, cheaper than can be accomplished by any other method.

The floating dipper dredge is more widely used in drainage work than is any other type of excavating machine. For work through wet land no other excavator will equal it in cheapness of construction of ditches having a cross section of from 100 square feet to 1,200 square feet. It is by far the most efficient machine to use where many stumps will be encountered. Owing to its limited reach it is not generally applicable to levee construction. Dipper dredges as constructed for drainage work range in capacity from one-half cubic yard to 4 or 5 cubic yards; the sizes most commonly used vary from 1 to 2 cubic yards. The smallest dredge costs about $5,000; the cost increases rapidly with the capacity of dipper. The floating dipper dredge should be operated downstream, where practicable.

In general, the clam-shell or orange-peel dredge is not well adapted to ditch construction, especially if there are stumps to handle. Certain types of soil, such as the muck of southern Louisiana, can, however, be handled to advantage with this machine. It is also suited to levee building when equipped with a long boom.

The drag-line scraper excavator is constantly increasing in favor in drainage work. It is especially suited to the construction of ditches and levees of large cross section, where the ground is sufficiently stable to support the machine. The scraper excavator is also suitable for ditch cleaning.

The various forms of so-called dry-land machines find quite extensive use in drainage. The dipper and orange-peel dredges of the dry-land type are suitable for use where sufficient water can not be had to float a dredge. The templet and the wheel types of excavators are applicable to open land where the soil is neither too hard nor too wet. The ditches cut by these latter machines are superior in hydraulic efficiency to those of similar section cut by any other type of excavator. The dry-land machines should be operated upstream.

The hydraulic dredge is not suited to ordinary drainage ditch construction. It has been used to some extent in cleaning ditches, and, with the use of slope boards, has in at least one instance made a satisfactory record in levee construction.

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