FORESTRY PAMPHLETS

Pamphlets on SILVICULTURE

" Vol.XIIII

Artificial Reproduction

Trees, Shrubs & Plants for Farm & Home Planting
By C.P.Halligan. Michigan Agricultural College
Bulletin #281. February, 1918.

2 Tested Forest Trees for Planting in Idaho.
By F.G.Miller. University of Idaho Agr.
Exper. Sta. Circular #5. Jan., 1918.

A Shade Tree Guide. By Alfred Gaskill.
Dept. of Conservation & Development, State
of New Jersey. 1918.

4 Steam Sterilization of Seed Beds for Tobacco and
Other Crops. By E.G.Beinhart. U.S.D.A.
Farmers' Bulletin #996. July, 1918.

Rodent Pests of the Farm. By D.E.Lantz.
U.S.D.A. Farmers' Bulletin #932. 1918.

6 The Spotted Garden Slug. By Wm. H. White.
U.S.D.A. Farmers' Bulletin #959.

Preventing Fruit Tree Injury by Field Mice.
Article by W.C.Dutton.

8 Dusting & Spraying Experiments of 1918 & 1919.
Michigan Agr. College, Special Bulletin #102.

Trees & Shrubs on the Farm. By O.B.Whipple &
C.C.Starring. University of Montana.
Circular #78, March, 1918.

10 Tree Planting Along Highways. Article from
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Article by W.E.Bontrager.

12 Rodent Protection for Fruit Trees. Treatment for
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18 Spraying Lawns with Iron Sulfate to Eradicate Dandelions. By M.T.Munn. N.Y.Agricultural Experiment Station, Geneva, N.Y. Bulletin #466 in two parts - Sept.,1919 and Dec.,1919.

Tree Planting in Texas Towns & Cities. By L.Wyman. Bulletin #11 - State Forester, Texas.

20 Nursery & Orchard Insect Pests. By L. Haseman. University of Missouri Agr. Exper. Sta. Bulletin #176. October, 1920.

An Investigation of the Dipping & Fumigation of Nursery Stock. By K.C.Sullivan. University of Missouri Agr.Exper.Station Bulletin #177. December, 1920.

22 Plant Inspection in Missouri. By K.C.Sullivan. University of Missouri Agr.Exper.Station Circular #101. December, 1920.

Forest Planting in Southern Michigan. By L.J.Young. Reprinted from Journal of Forestry, Feb.,1921.

24 Hypertrophied Lenticels on the Roots of Conifers & Their Relation to Moisture & Aeration. By G.G.Hahn, C.Hartley & A.S.Rhoads. Reprinted from Journal of Agricultural Research.

A Chlorosis of Conifers Corrected by Spraying with Ferrous Sulphate. By C.F.Korstian, C.Hartley, L.F.Watts & G.G.Hahn. Reprinted from Journal of Agricultural Research, May 2, 1921.

26 Growing & Planting Hardwood Seedlings on the Farm. By C.R.Tillotson. U.S.D.A. Farm.Bull.#1123.

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MICHIGAN AGRICULTURAL COLLEGE

EXPERIMENT STATION

HORTICULTURAL SECTION

TREES, SHRUBS AND PLANTS FOR FARM AND HOME PLANTING

BY

C. P. HALLIGAN

EAST LANSING, MICHIGAN
1918

The Bulletins of this Station are sent free to all newspapers in the State and to such individuals interested in farming as may reqvest them. Address all applications to the Director, East Lansing, Michigan.

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TREES SHRUBS AND PLANTS FOR FARM AND HOME PLANTING

BY C. P. Halligan.

INTRODUCTION

Why One Should Plant.

(a) Because of a desire to make the farm home a better place in which to live.

The rural ideal today of making the country a better place in which to live begins with the improvement of the interior conveniences of the house and the exterior surroundings of the home. The attachments that are formed for the home are frequently associated with the trees, shrubs and flowers that surround it. A farm house standing out in its nakedness to the severest storms of winter and the torrid heat of summer with no trees to shelter it or shrubs to clothe it, is hardly conducive to the formation of loving thoughts and tender memories. From such farms the young folks migrate to the cities and the old folks to the towns. If the farm is worth farming, then the grounds about the house are worth developing into a pleasing home grounds.

(b) Because it is one's duty to plant.

Every man owes it to his family, his neighbors and his community to develop his property and maintain it in as neat and attractive a manner as his means will permit.

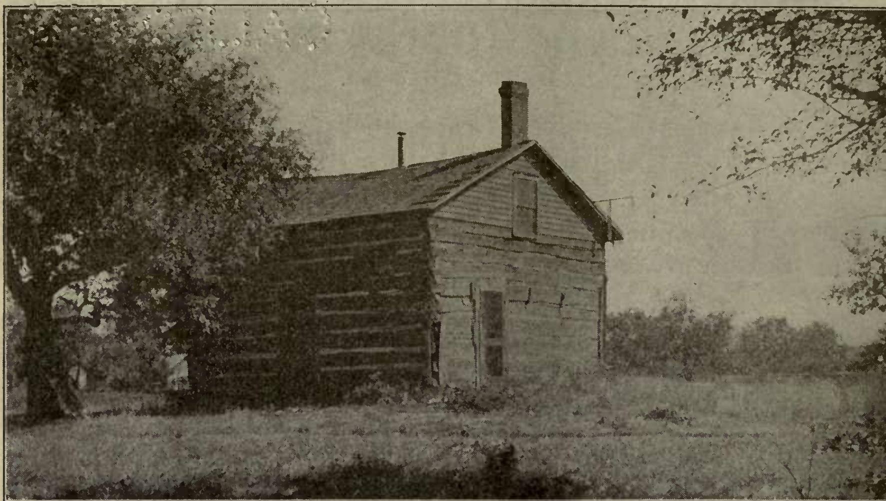
The environment of children to a large degree measures their ideals. Noble characters and lofty ideals are not formed amid unclean and unkempt surroundings. Healthy children with wholesome thoughts demand an environment that is healthful, clean and inspiring.

The value of property for living purposes depends considerably upon the general appearance of the surrounding property. It no longer remains a personal privilege for one to neglect the appearance of his grounds as such neglect detracts from the value of the property of his neighbors as well as from his own.

A community that is characterized by pleasing homes that are neat and trim in appearance constitutes an inviting location for desirable people seeking new farm sites. The value of such farm properties is measured upon this factor as well as upon the general productive value of the land. It is a public duty, therefore, of all who are fortunate enough to possess a bit of land surrounding the house, to make the place as pleasing, interesting and livable as a home grounds should be that its attractiveness may enhance the beauty of the street and community of which it is a part.

(c) Because it is a good financial investment.

A few dollars and a little labor spent in developing and improving the home grounds, in properly planting a few trees and in arranging shrubs around the grounds, will, in a few years, often increase the financial value of the property more than a similar amount spent in any other manner.



A log cabin; the farm home of the pioneer, typical of the first stages in the agricultural development of Michigan

In fact, the value of a stately huge elm, majestically overspreading the house and lawn, can hardly be reckoned in dollars. Such well developed trees and plantings that have been judiciously placed are simply the basis of all that is desirable about them.

If farmers would invest more of the profits of the farm in improvements on the place, rather than in outside investments that they know less about, making the farm home annually a better place in which to live, many of them would be far more comfortable today both financially and physically.

Invest at least a part of the profits of the farm each year in making the place a more pleasing and comfortable one in which to live and one will feel less disposed to give it up and retire to the town. Make the farm grounds themselves worth retiring upon. Make this, a well improved farm, the heritage of your children and more of the younger generation will not only stay on the farm but a farm for them worth remaining on will be the result.

SELECTION OF BUILDING SITES

In the selection of a site for any building, there are three determinant requisites. The first of these requisites is *soil drainage.* A poorly drained site for a building is unhealthful, disagreeable and frequently a very costly site to maintain. A well soil-drained site is of first importance.

Air drainage is of equal importance. A damp or stagnant air is as objectionable to the health as poor soil drainage. The site for buildings, therefore, should be such as to possess a good natural circulation of air. Beware of hollows or pockets on hill sides where the cold damp atmosphere

The farm home as desired today, made pleasing by good architecture and proper landscape plantings

collects and has no channels through which it may drain away. Generally, where we find good soil drainage, we also find it well air drained but there are many exceptions to this rule.

The third requisite is *sunshine.* Sunshine makes a dwelling bright, cheerful and attractive as well as exercising a great beneficial influence in maintaining its healthfulness. Direct exposure to sunlight kills most germs. Germs thrive best in a dark, moist atmosphere. A dwelling or barn then, with plenty of windows exposed to the direct rays of the sun, is a great help in maintaining pleasant and healthful surroundings.

That a site for a building should possess these three requisites, namely, soil drainage, air drainage and sunlight is of first importance.

Selecting the House Site. The future value and pleasantness of the farm home will depend also upon a proper consideration of the aesthetic qualities of the site for the house.

The house should be situated *some little distance back from the main road.* It is a common error to find the average farm house entirely too near the public road to give that privacy and air of dignity and refinement which may be obtained by a proper treatment of a farm grounds, possessing an ample front lawn. Today, with the increased traffic on the country

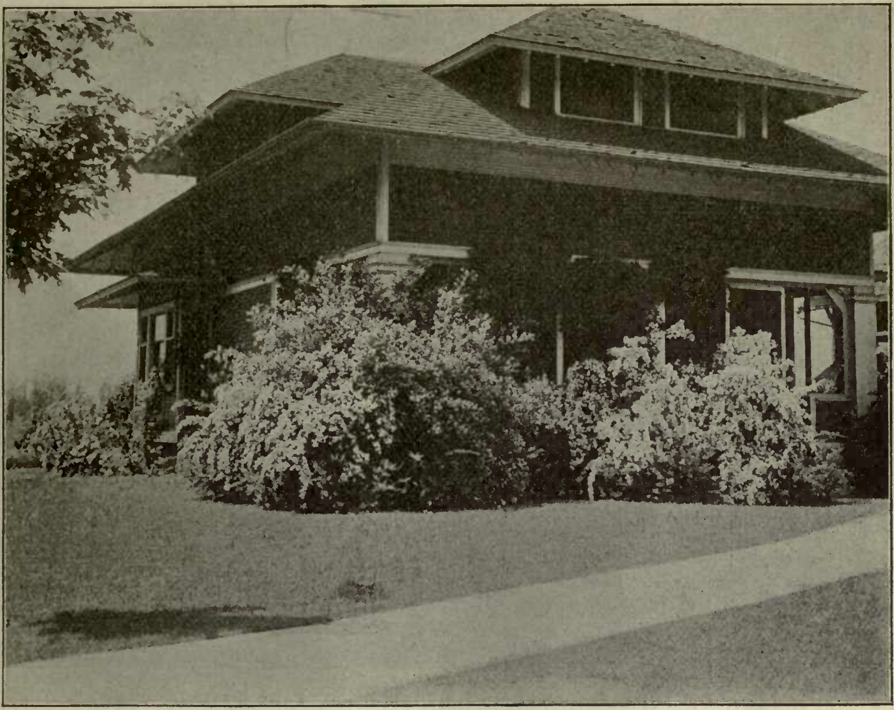
Before Planting. Is planting worth while? A house with no trees to shelter it or shrubs to clothe it. See the following picture.

roads, the dust nuisance becomes a very serious problem, the principal solution of which consists in keeping the house well back from the road and sometimes planting heavily along the roadside.

In selecting the site for the house, advantage should be taken of any vistas that are especially pleasing. If the house is placed so as to obtain a beautiful view over a lake, along a river or across a valley, it will enhance the value of the property without increasing its cost. Today, with the ever increasing demand for country homes, these vistas prove very desirable assets.

It is well also, in selecting a site, to consider the *exposure*. A site that is more or less protected from the north and west with an open exposure to the south and east, is ideal. On many farms, a site sheltered by a woods, hill or other natural condition, may be found which would prove a great protection during the winter months. Whether or not these conditions are available, there is always room enough on the farm to place the buildings in such a way as to receive the greatest amount of sunlight, especially during the winter. Whereas it seems to be the prevalent opinion that a building should run directly north and south or east and west, it is these problems of sunshine and exposure that should determine its direction.

Any topographical feature of the land might also largely determine the location of a building. The position of a group of large trees or a rugged boulder might prove the chief determinant.



After Planting. Same place as preceding picture but about three years later. Was planting worth while?

A slight knoll generally makes an ideal site for a building. If the land is level and such a spot is not available, a building should be set rather high on its foundation and the soil from the excavation with a little additional filling, will tend to obtain at least a portion of these advantages. On farms that are hilly and rough, ideal sites may be found,—sites, too, that would prove of very little value for farming purposes.

THE PLANTING PLAN

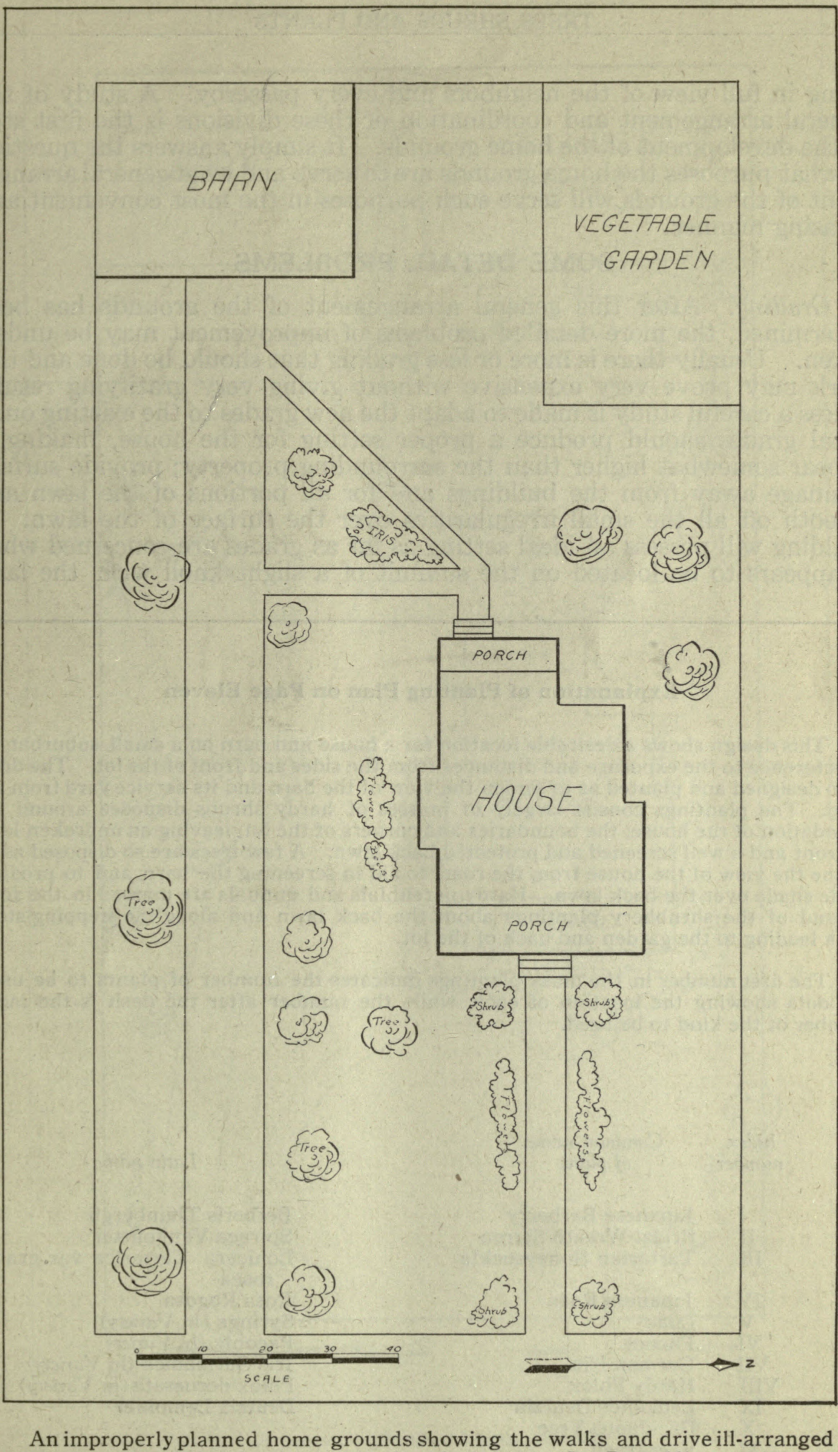
In the development of the home grounds, there is need of a preconceived plan. This plan should be conceived in a general way when the building sites are being selected but the details may best be worked out after the buildings have been constructed and the drives and walks have been laid out. While the need for a plan is real and its existence essential, there is no necessity of carrying it out all at once. The execution of the plan may be gradual; the most important parts of it may be developed first and the remaining parts as circumstances permit. In fact, this gradual development is often desirable as the experience gained the first year or so often suggests desirable changes for future work. Under such conditions, a plan drawn to a definite scale, furnishing a definite record for future reference, is very essential as it insures the progressive development of the scheme that otherwise might be forgotten.

Masses of hardy shrubs about the foundation of the house tend to harmonize it with its site.

GENERAL DIVISIONS

An ideal landscape development of the home grounds involves a study of the general arrangement of the various divisions of the grounds to make them as serviceable and livable as possible. For example, there should be a service division for performing the necessary but often unsightly functions of a dwelling; a place for the ingress and storing of supplies and the egress of wastes; a lawn for the drying of clothes, a vegetable garden and places for any other such desirable purposes as the amount of available space will permit. This division should be designed to perform these functions most conveniently and to be maintained in a most tidy manner. It has been said that the typical American style of development about the home grounds consists in maintaining a "Queen Anne front and a Mary Ann back." This typical unsightly appearance of many back yards is largely due to an arrangement of the service division that does not conveniently and thoroughly serve these necessary functions.

The entrance division of the property usually includes the front lawn and entrance walks and generally is that portion of the property by which the public receives its impression of the entire place. The walks should be apparently direct and convenient while the appearance of the division, as a whole, should be trim and tidy, simple, dignified, hospitable and harmonious. Often there may well be other divisions, as a living division where the family may enjoy the privacy of family life out-of-doors without



An improperly planned home grounds showing the walks and drive ill-arranged and the plantings cluttering the lawns. (See Page 11)

being in full view of the neighbors and every passerby. A study of the general arrangement and coordination of these divisions is the first step in the development of the home grounds. It simply answers the question of what purposes the home grounds are to serve and what general arrangement of the grounds will serve such purposes in the most convenient and pleasing manner.

SOME DETAIL PROBLEMS

Grading. After this general arrangement of the grounds has been determined, the more detailed problems of improvement may be undertaken. Usually there is more or less grading that should be done and this work may prove very expensive without giving very gratifying results unless a careful study is made to adapt the new grades to the existing ones. Ideal grades should produce a proper setting for the house, making it appear somewhat higher than the surrounding property; provide surface drainage away from the buildings and for all portions of the lawn and smooth off all the small irregularities over the surface of the lawn. A building will possess an ideal setting as far as grades are concerned when it appears to be located on the summit of a slight knoll with the land

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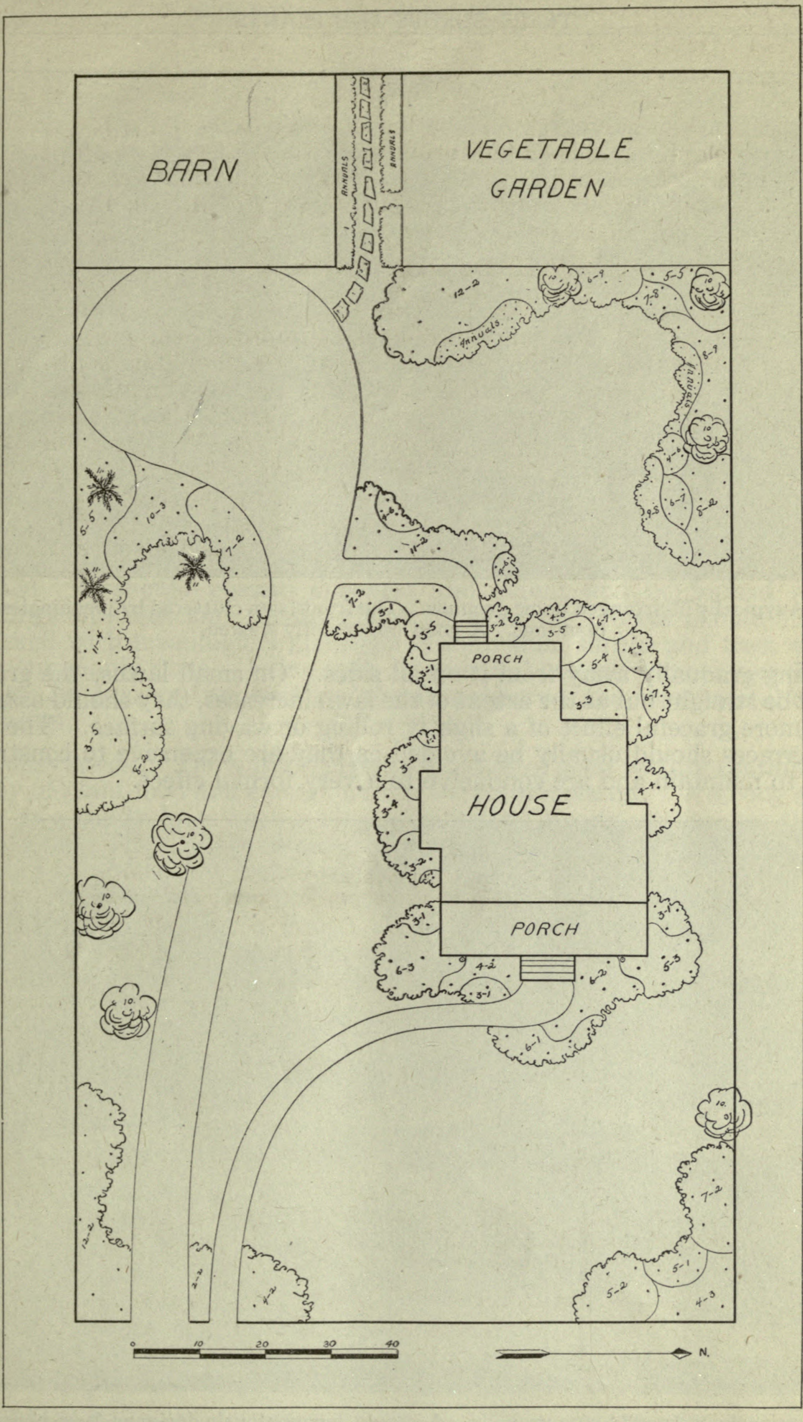
Explanation of Planting Plan on Page Eleven

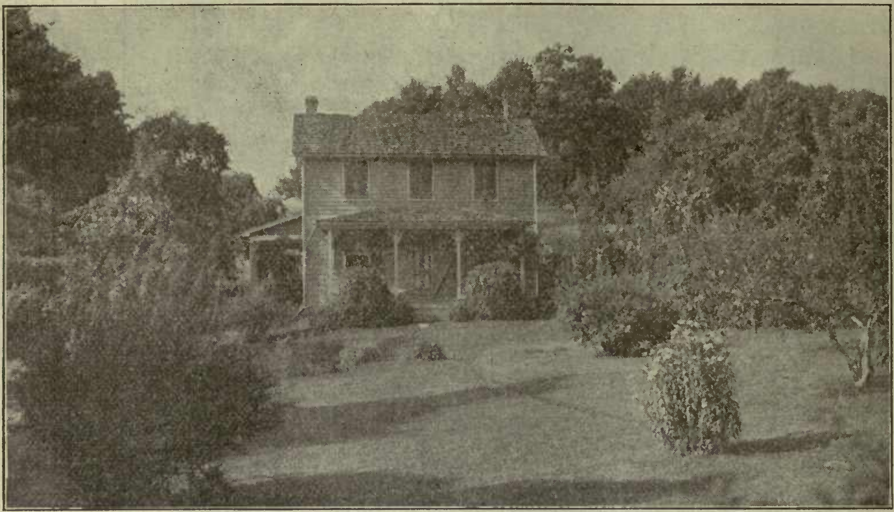
This design shows a desirable location for a house and barn on a small suburban lot in reference to the exposure and distances from the sides and front of the lot. The drive is so designed and planted as to screen the view of the barn and its service yard from the road. The plantings consist largely of masses of hardy shrubs disposed around the foundation of the house, the boundaries and corners of the lot, leaving an unbroken lawn in front and a well screened and protected back lawn. A few trees are so disposed as to frame the view of the house from the road, to aid in screening the barn and to produce some shade over the back lawn. Hardy perennials and annuals are massed in the foreground of the shrubbery plantings about the back lawn and along the stepping-stone walk leading to the garden and back of the lot.

The first number in the mass plantings indicates the number of plants to be used, the dots showing the location of each, while the number after the dash is the index number of the kind to be used.

Index number	*Common name of plant*	*Latin name*
I	Japanese Barberry	Berberis Thunbergii
II	Bridal Wreath Spirea	Spiraea Vanhouttei
III	Tartarian Honeysuckle	Lonicera Tartarica var. grand. rosea
IV	Japanese Rose	Rosa Rugosa
V	Lilac	Syringa (*In Variety*)
VI	Paeony	Paeonia (*In Variety*
VII	German Iris	Iris Germanica (*In Variety*)
VIII	Hardy Phlox	Phlox decussata (*In Variety*)
IX	Lemoines Deutzia	Deutzia Lemoinei
X	Deciduous Tree	
XI	Evergreen	
o	Vine	



A properly planned home grounds,



A typically ill-arranged home grounds. The front lawn cluttered by meaningless plantings. A good opportunity wasted.

sloping gradually away from it on all sides. On small lawns, the grades may be straight but as the extent of the lawn increases, they should assume the more graceful effect of a slightly rolling or waving surface. The use of terraces should usually be avoided as they are expensive to construct and to maintain and are conducive to a very formal effect.

A properly arranged home grounds. A simple, harmoniously designed farm house, situated well back from the road on a slight knoll, with a wide, unbroken front lawn framed along the back and boundaries with trees.

WALKS

Walks. On the small place, the designing and laying out of the walks and drive is a simple problem. They should be as direct and as convenient as conditions will permit; but on the larger place where the house is situated some distance back from the road, their design is often a more perplexing problem. Besides being convenient and direct, they should be graceful and pleasing in their lines, making them harmonious with the natural landscape effect of the grounds. Frequently, they may enter the property near the front corners and in simple sweeping curves approach the building, leaving a broad unbroken front lawn effect. Such an effect adds to the apparent extent of the grounds and produces an ideal setting for the buildings and plantings. It is desirable, therefore, in arranging the walks and drives to keep them well to the sides and boundaries whenever conditions permit.

LAWNS

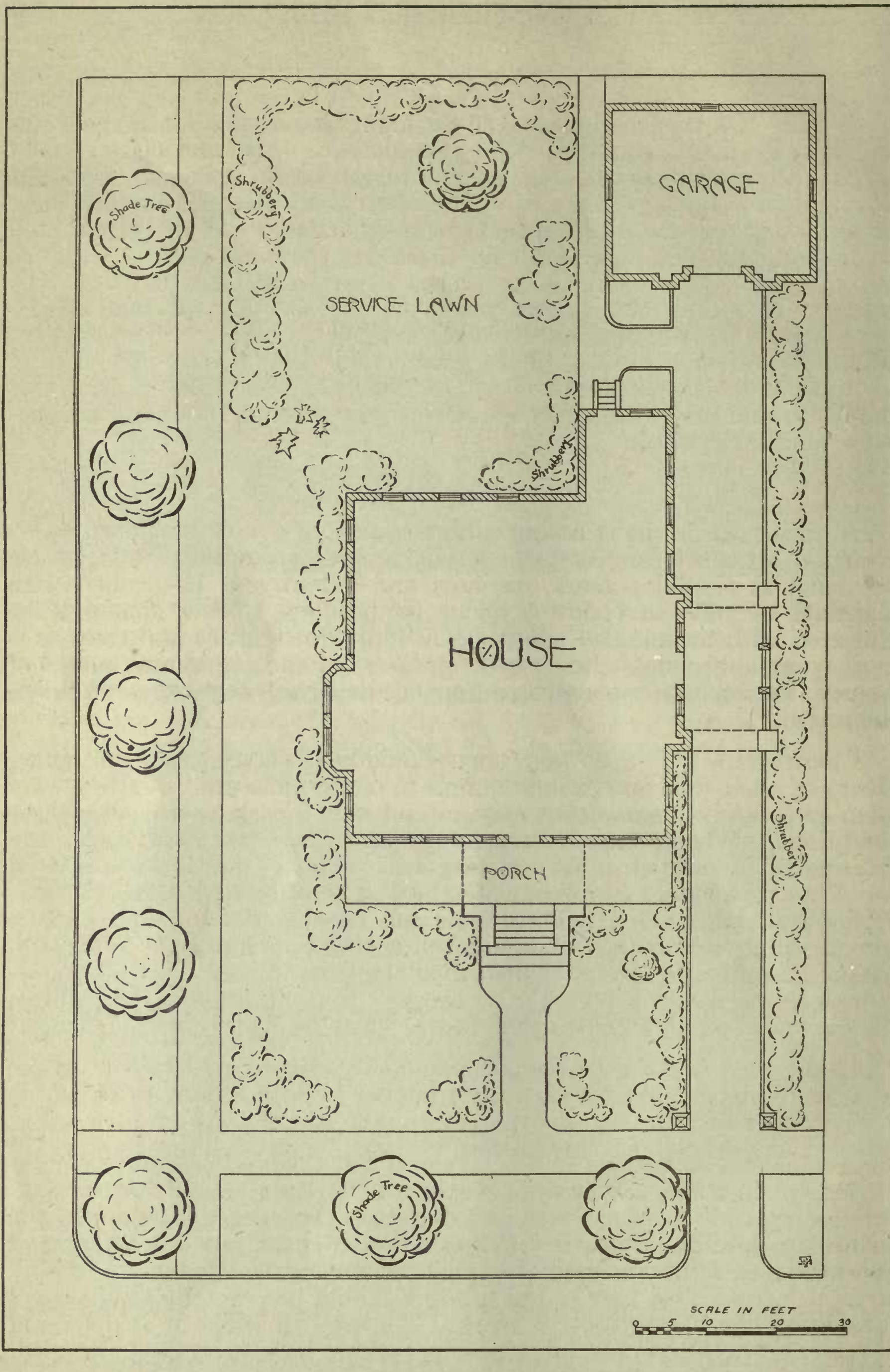
A good lawn is the most important feature of a well developed home grounds. It is often referred to as the canvass upon which the picture is painted. It should possess openness and extent and be framed with plantings of trees and shrubs about its borders. Never should it be cluttered with meaningless plantings of individual shrubs and trees as is most commonly done. Being such an essential and permanent source of beauty, its construction and maintenance deserves the most careful consideration.

Construction. The *soil* for a lawn should be of good texture containing plenty of plant food and enough humus to retain moisture. A strong clay loam or a sandy loam with a clay subsoil most nearly approaches these conditions. When a lawn is to be constructed upon light sandy soil, a top dressing of about two inches of clay with a heavy application of well rotted manure should be mixed with the first three or four inches of sand. Frequently, in building a house, the soil excavated from the cellar is spread about covering the good top soil with a poor sub-soil. This subsoil is of poor texture, contains little available plant food and is an extremely poor soil for lawns. Where it is necessary to use this sub-soil for filling, the top soil should be first removed to be later replaced on the surface.

In the *grading* of a lawn, first endeavor to obtain good surface drainage; see that there is a slight slope away from the buildings; that there are no low pockets where water may stand during the winter and spring, and that the area as a whole, is either naturally or artificially well drained.

Except in some very special cases, a level lawn should not be constructed. It lacks naturalness and decreases the apparent extent of the lawn. In grading, endeavor to preserve the slight natural slopes and curves of the land, remembering that nature never produces perfectly level surfaces. This part of the grading should be carefully studied and considered before starting the work. The way in which it is done will determine whether a graceful, pleasing, natural lawn is secured or a stiff, restrained, unsatisfactory one is the result.

After the general slopes have been established, the land may be harrowed if necessary and any small uneven places smoothed off.



A simple planting design of a small corner lot, showing the arrangement of the plantings, drive and garage with the service lawn screened by plantings from the road.

If the land has been allowed to remain over winter in a rough condition, the soil will have become well settled by spring and will be ready for the final work before seeding. Pick off all the stones which have come to the surface during the winter and then go over the land with a shallow harrowing or raking. If it can then be rolled, the small uneven spots will become very apparent and they can then be leveled off with a hand rake. By re-rolling and re-raking the land in this way, the surface can be made as smooth and even as desired.

Fertilizers. Well decomposed stable manure is the best general purpose fertilizer for lawns. It contains all the chemical elements essential for plant growth and adds humus to the soil, thus making it more retentive of moisture and also improving its texture. If this can be used, a heavy dressing should be applied. A ton to two thousand square feet would not be too heavy.

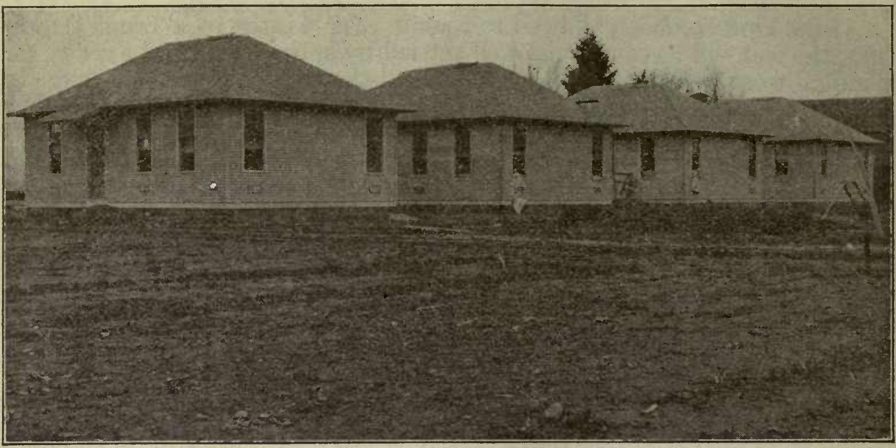
Chemical fertilizers may be used to advantage after the grass is well started but should never be applied at the seeding time as they may kill the young roots which come in contact with them during germination. It must be remembered also, in using commercial fertilizers that they never improve the physical condition of the soil. There is no humus added to the soil by their use and hence the soil texture is not improved. It is simply an addition of the essential food elements and should always be regarded as such. They are easily applied, contain no weed seeds and may be readily obtained.

Some of the most desirable forms of chemical fertilizers for lawns are fine ground bone, wood ashes, and the high grade forms of complete fertilizers. Ground bone is a very good form of fertilizer for lawns and although it contains principally phosphoric acid, it furnishes some nitrogen and lime. Unleached hardwood ashes are used as a source of potash and if applied each spring soon after growth begins, will generally prove very beneficial. Complete high grade fertilizers for lawns may be obtained from almost any fertilizer dealer and, while more expensive than the other forms, they are often quite efficient in maintaining the lawn.

Although the amount of fertilizer advisable to apply will depend much upon the condition of the soil as well as upon the form and strength of the fertilizer to be used, a dressing of about 2.5 pounds per hundred square feet would be a moderate application under average conditions.

Varieties of Grass for Lawns. The best variety of grass for lawns, under general conditions in Michigan, is Kentucky Bluegrass (*Poa pratensis*). While it is rather slow in starting, it produces a permanent lawn of fine texture and of a rich green color. The crown of the plant sets very close to the ground thus permitting close clipping and the plant, after becoming established, spreads rapidly by underground roots.

Although a permanent bluegrass lawn may be desired, it is often advisable to sow other varieties with the bluegrass seed. Of the rapid growing grasses that may be used for this purpose, the English rye grass (*Lolium perenne var. tenue*) is one of the best. It is an annual grass and a little coarse in leaf, but starts rapidly, produces a very early effect and covers the ground which might otherwise be occupied by weeds. Do not use oats, rye or timothy for this purpose.



A row of cottages before planting. Note how bare and bleak they appear. See the picture on the following page.

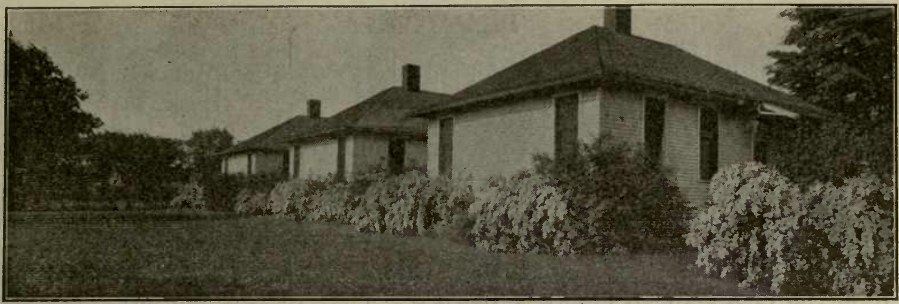
Redtop (*Agrostis alba*) is a thick growing grass which produces a good lawn effect the first season. It is of a finer texture than rye grass but does not grow quite as rapidly on the start. It grows better under adverse soil and moisture conditions than most other grasses.

White clover (*Trifolium alba*) is frequently used on lawns as many people desire the appearance of the white clover blossoms in the summer. Others object to its tendency of giving the lawn a spotted effect.

On a very sandy soil the Rhode Island Bent grass (*Agrostis conina*) does well, while in very shady places the Woodland Meadow grass (*Poa nemoralis*) may be used. Where the lawn is on high, dry situations or slopes the Sheeps Fescue (*Festuca ovina*) will be found desirable, while on low wet places the Various-leaved fescue (*Festuca heterophylla*) will thrive.

For the average lawn, a good mixture is one-fourth Fancy Red Top, one-fourth English Rye grass and one-half Kentucky blue grass. If the area to be sown is small and the conditions of soil or exposure somewhat variable, it is advisable to buy a high grade prepared lawn mixture from a reliable seedsman. This mixture will generally contain seed adapted to various conditions and will prove more convenient and frequently better than the homemade mixture on such a small scale.

Frequently grass seed contains a great many weed seeds, often of a kind that may prove a serious nuisance and expense to get out of the lawn if they once become established. It is best to buy only the best seeds from the most reliable seedsmen. If a large quantity is to be procured, it would be advisable to send a sample to the Division of Botany of the State Experiment Station where it will be examined for purity free of charge.



The same cottages as in previous picture three years after planting. The simpler the architectural features the greater is the importance of plantings.

Sowing the Seed. In starting a lawn use plenty of seed, one and one fourth pounds to about 1000 square feet or fifty pounds to the acre (43560 sq. ft.) being none too much. Thick seeding chokes out weeds and assists in producing a quick effect.

Select a day when there is no wind to sow the seed. Early in the morning or about sun down is a very good time, and if just before a rain, so much the better.

By sowing the seed in the following way, an even stand is quite assured: taking one half of the amount of the seed to be sown and beginning at one end of the lawn, sow in parallel strips until the entire lawn is covered; then take the remaining one half of the seed and sow in strips in the other direction. If this is properly done, there should be no streaks or vacant spots in the future lawn.

After sowing the seed, unless directly followed by rain, the soil should be rolled. Raking or harrowing after sowing is apt to bury the seed unevenly.

Maintenance. After the grass has grown to a height of from four to six inches, it should be given the first clipping, being careful not to cut very close. A scythe is better for this cutting than a lawn mower as it will not pull out the young plants or cut as close as the mower. The future cuttings should be performed frequently enough to permit the clippings to remain on the lawn without being unsightly. These clippings if allowed to remain, will form a dense mulch around the base of the plants and protect the soil from drying out during the summer months. Cut frequently then but not too close.

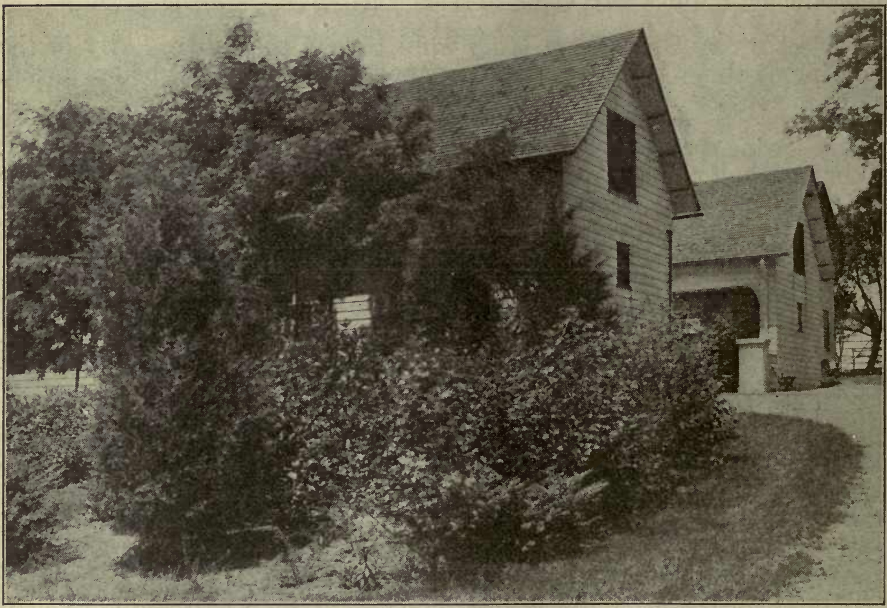
Additional seed should be applied to all lawns at least every spring and often another sowing would prove beneficial the latter part of June or in September.

The most effective method of controlling weeds in lawns is by securing good drainage to the soil, keeping the lawn well supplied with plant food and the soil well filled with pure seed. Make the conditions for plant growth most favorable and there will be little chance for weeds to gain a foothold and develop.

PLANTING

Very ordinary looking buildings can be made attractive and homelike if the planting is properly done. It may be said that the less prominent the architectural features of a place, the greater the relative importance of the plantings. Hence it is very important that considerable attention be given to the planting of the ordinary farm house.

Functions of Planting. Before any successful attempt may be made in this line, one must first inquire as to the functions or purposes of the plantings to be made. In planting farm grounds, let it be realized that it is the endeavor to create a picture. That in this picture there are given as its elements, a farm house and other buildings,—roads, walks, lawns and other more or less separated elements. To unite these several disconnected parts into the production of one harmonious composition is the leading function of the plantings. To arrange the plantings about



Farm buildings may be made to harmonize with the home grounds by appropriate planting,

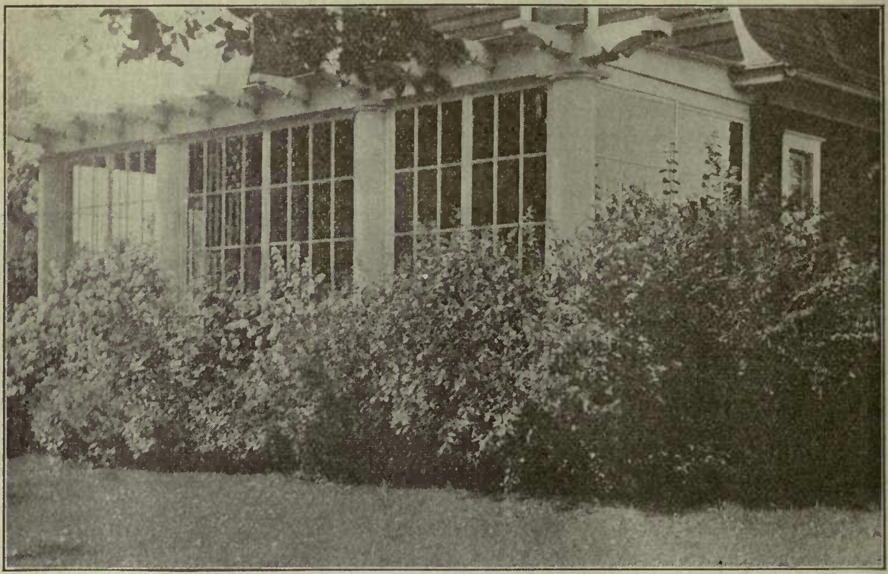
the house that the building may seem a natural outgrowth of the spot; to so arrange the plantings on the grounds that each and every planting may seem dependent upon the presence of every other planting or other element in the design, is the purpose of the planting. When it can be realized that these plantings are made not primarily for the sake of their own individual beauty but more because of their relationship to the design as a whole, to the picture about to be created, the first principle to guide one in planting has been mastered.

The planting of each and every grounds is a new problem, differing in certain respects from every other one. There are no definite rules then that can be given to guide one in the work; no ideal plan which may be drawn to serve all places; but there are a few general principles which may be suggested as a guide when solving many of these problems. Before any planting design is made, the grounds should be studied in reference to the general arrangement that is most serviceable. The style of architecture of the house, the position and character of any large trees already on the grounds, the slope and general character of the land, and any other natural condition should be studied to "see what kinds of beauty,

Plantings used to screen an unsightly view of neighboring barns.

what general character of pleasing appearance these conditions most readily suggest." Each and every home grounds is more or less suggestive of a certain type of beauty which may be brought forth and emphasized with the least difficulty.

After perceiving this type of beauty, one must then proceed to make the necessary details of arrangement, emphasize and enhance the character thus selected. One will first find certain elements which detract from the beauty of the grounds, which are defects in the picture, and should be screened by the use of plantings. Views within the grounds, such as of the henhouse, barnyard, a boundary fence or service drive and other unsightly spots; views beyond the grounds, as of a neighbor's shed, the back of a neighbor's barn and other views hardly pleasing and acceptable to the sight,—all these should be entirely hidden from view by the use of plantings, or at least partially broken up to minimize their unsightliness.



A mass planting of hardy shrubs about the base of the porch tends to harmonize it with the lawn.

There are other elements in the design which should be just as carefully preserved and enhanced by plantings. The most pleasing lines and portions of the house, for example, may be emphasized and carefully preserved to the view. A wide sweep of open lawn, with a border and background of trees and shrubbery, is always a pleasing and acceptable sight. Vistas without the grounds, as of a distant woods, a winding river or a neighboring farm house and even the travel upon a public road, are often welcome sights which add to the pleasure and value of the grounds. It is especially important that these vistas be carefully preserved from the living rooms of the house, not always from the parlor but from those rooms where the family spend the major portion of their time. The plantings then serve a very important function by concealing the defects in these places and by enhancing those parts that are most pleasing. Thus, it may be seen how beautiful and attractive some of the ordinary looking farms of today may become by the proper use of plantings. How much more important this landscape use of plantings becomes on a common, ordinary looking farm where there are generally so many unpleasant sights which detract from the looks and very often from the value of the farm.

Plantings, when improperly used, may detract from the value and looks of the farm as well. The effect of a well-designed farm house is very frequently ruined by poor plantings. Trees planted too thickly

Mass plantings of trees and shrubs should be disposed about the boundaries of the lawn.

or too closely in front of the house; a lack of harmony in the design of the grounds to that of the house; plantings so placed as to hide the house from its most pleasing point of view—these are a few of the many causes which often spoil the effect of a well designed house by improper plantings. Let it be remembered then that plantings are to enhance rather than to detract from the expression already given by the design of the house and to harmonize it with its site.

There are three general rules of guidance tn arranging the plantings:

First,—avoid straight lines in planting. The general effect of all lines in planting should be graceful and naturalistic rather than stiff, formal or artificial. Plantings should seem to be a natural outgrowth of the spot rather than a crude piece of man's handiwork.

Second,—arrange the plants in groups and masses, selecting few kinds and many of each rather than many kinds and few of each.

Avoid planting meaningless, isolated specimens over the lawn. Naturalistic masses and groups of plants are necessary to give structural character to the design and each group or mass should consist of many specimens

Plantings properly arranged to enhance the architecture of the house

of but a few kinds, rather than one or two specimens of several kinds. The kinds of shrubs selected should be repeated in the various groups and masses not precisely in the same combinations but sufficiently so that the effect of one planting may be harmonious with the others. In this manner unity of effect may be obtained.

Plantings should be massed about the base of the buildings, using many specimens of but few kinds rather than one or two specimens of several kinds. Bridal wreath spirea, (*Spiraea Vanhouttei.*)

Third,—plantings should be massed about the base of the buildings, grouped about the junctions or curves in the walks, massed about the boundaries and corners of the property but not usually along the front boundary of the property.

When arranged in this way, an open lawn bounded with naturalistic plantings of shrubbery and trees will be the general effect.

In arranging these plantings, they may perform other desirable functions also. They may be arranged to shelter the house from the winter storms and the summer heat, or to frame desirable vistas and thus accentuate their attractiveness. Masses of shrubs may be used to take the place of an undesirable fence or hedge. They may be planted to prevent people from wearing paths across the lawns and to unify the walks, buildings and other elements of the grounds into one harmonious design.

Shrubs planted in the corners of the entrance porch generally prove effective.

How to Plant. The planting should be done early enough in the spring so that the shrubs will be well established before the heat and drought of summer overtakes them. In preparing the beds, they should be dug to a depth of a foot or more and well manured. The distance of setting them depends largely upon the size of their growth. Japanese barberries should be planted two feet apart, spireas three and one-half feet and lilacs about four to five feet. In three years, when set at these distances, the branches should be so intermingled that their individuality in the beds is lost and a unified mass effect produced. In transplanting, keep the roots moist and prevent them from being exposed to the sun and wind any longer than necessary. Set the plants slightly deeper than they stood in the nursery and pack the best fine soil firmly about the outspread roots. If the soil is dry, water after planting. It will help to compact the soil about the roots and keep them moist. The tops may then be pruned back to balance the loss of roots, leaving a few large buds on each of the strongest shoots.

WHAT VARIETIES TO SELECT

Shrubs

The choice of varieties is perplexing because there are so many handsome shrubs all of which seem most desirable to the home garden maker. A few of the good old standbys that are handled by every nurseryman and sold by the millions, that are sure to give one his money's worth and are safest for the beginner to tie to are given in the following list.

Spireas. First of all there is the bridal wreath spirea, *Spiraea Vanhouttei,* the most popular spring flowering shrub. Its remarkable freedom of bloom and beautiful foliage produced on branches drooping gracefully to the ground makes it exceedingly attractive. This spirea, which is only one of a large group of Spireas, is very hardy and grows well upon any moderately rich and well drained soil. It attains a height of about five feet and is particularly adapted for mass plantings about buildings and porches, along walks and drives or around the boundaries of the lawn. Of the other spireas, there is the double-flowered spirea that one sees everywhere named *Spiraea prunifolia* because its leaves resemble those of the Prunus or plum. *Spiraea arguta,* altho not as well known, is a most desirable early spring flowering shrub with small delicate foliage and white flowers. It is particularly adapted for planting in the foreground of other higher and coarser growing shrubs. For summer floweirng, the species is represented by *Spiraea Bumalda* var. Anthony Waterer that blooms quite continuously from the middle of June until frosts overtakes it in the fall. Its flowers are produced in corymbs or flat flower heads of a rosy crimson color, sometimes approaching a magenta. Where a low shrub is wanted for summer effect, this is one of the best.

Shrubs massed about the base of trees relieve the bareness of the trunks and tend to unify them with the surrounding lawn.

Thunberg's Barberry. It would be hard to name a shrub as cosmopolitan in its characteristics, combining as many desirable qualities as the Japanese barberry, *Berberis Thunbergii.* It is one of the few shrubs that is attractive at all seasons of the year. In the spring and summer its graceful branches are clothed with small yellowish green leaves that change to a bright scarlet in the fall. Later they are shed to expose the scarlet berries that enliven the landscape all winter. While a sandy loam soil seems to be ideal for the barberry, it will be found thriving equally well on practically all types of soils that are well drained and seems hardly more particular over exposure. The San Jose scale, plant lice and other pests seem to painstakingly avoid it. The graceful form it assumes and its low habit of growth make it suitable for filling in small spaces such as between walks or buildings or for planting in front of Spireas and other higher growing shrubs. There is nothing better to use where a low ornamental hedge is desired than this barberry that shifts for itself after it is once established.

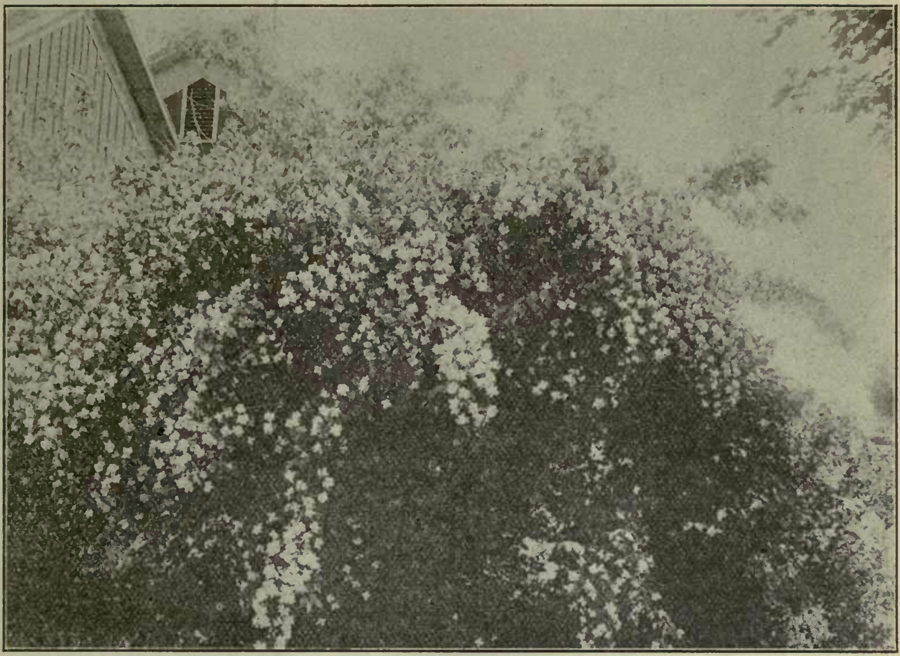
Sorbaria sorbifolia generally known as the Ash-leaved Spirea, is desirable for planting steep banks.

Lilacs. The most common and still most indispensable of the shrubs is the lilac. There are so many desirable improved varieties of this old time flower that even if one were given a few bushes of the old-fashioned type by some kind meaning neighbor, one could not afford to plant them, the new improved ones are so much superior. They produce larger and better flowers over a longer season. Therefore, go to a nurseryman and get something that will be different and better than this old-fashioned type. There become acquainted with Marie Legraye, a beautiful white; Mad. Lemoine, the best double white; Dr. Regel, a handsome rosy pink; Chas. X, an attractive rosy purple; Toussant L'Ouverture, a very dark carmine colored in bud, turning to a violet-red when in full bloom and an endless list of other improved sorts of the old fashioned lilac, *Syringa vulgaris*. Then, there are other species of lilacs that include at least one other type that should be used. For landscape effects it is to be preferred to any of the former group because it seems to be more graceful in its growth with smaller leaves and large, open, gracefully drooping panicles of reddish purple flowers. This is the Rouen Lilac listed in the catalogues as *Syringa rothomagensis*. The purple Persian lilac is very similar to it but more dwarf in its growth. For screens and backgrounds of shrubbery masses, used in separate colors rather than mixed, lilacs produce a most attractive effect in late spring.

Lilacs produce excellent effects when planted in masses on banks with a proper background of trees.

Mock Orange. The mock orange or syringa bush is another large, high growing shrub that is prized especially for its fragrant white blossoms that are so abundantly produced in June. The old-fashioned variety, *Philadelphus coronarius,* is the most fragrant but the newer varieties such as *Philadelphus coronarius grandiflorus,* produce flowers over twice the size and of a purer white. The yellow leaved sorts are not as vigorous or free flowering and should be used very sparingly. The green leaved sorts are very hardy and easily grown on any soil of moderate fertility.

Snowball. While the old-fashioned Snowball that was formerly planted in every yard is now considered of little value because its foliage is annually ruined by plant lice, its place has been taken by another bush called the Japanese Snowball, *Viburnum tomentosum plenum.* The flowers of this shrub are quite similar to the common Snowball but appear more attractive and of a purer white against the heavy dark green foliage of the bush. It delights in a rich moist soil and may be planted along the north side of buildings, a northeastern exposure being ideal. Although not entirely hardy in the northern districts, its superiority over the common snowball, both in foliage and flower, makes it a most desirable shrub. There are many other Viburnums also that are used by landscape gar-



The mock orange (*Philadelphia coronarius*) is one of the most cosmopolitan shrubs for home planting, being hardy, free from insects and diseases and easily grown.

deners that are more particularly adapted to the planting of parks and for producing other very naturalistic effects. Most of them are not as showy in flower but produce excellent summer effects by their fruits.

Bush Honeysuckle. The bush honeysuckles are very acceptable in plantings for the summer effect of their berries. While many produce beautiful spring flowering effects in white or pink, they are prized more for the red coral-like berries that color these plantings in midsummer after most of the shrubs are through blooming. *Lonicera Morrowii* is one of the best varieties for this purpose while *Lonicera tartarica* var. *grandiflora rosea* is one of the most effective in flower.

Weigela. A class of popular shrubs often confused with the honeysuckles, possibly because of their trumpet shaped flowers, is the *Weigela* or *Diervilla.* Although the latter is now considered the standard botanical name, in many of the catalogs, it is still listed as Weigela. Of the many varieties in pink, white or red that are now listed of this group, the old-fashioned pink flowering *Diervilla florida* continues to lead in popularity. There is another variety, *Diervilla hybrida Eva Rathke,* that is also used considerably by those familiar with its qualities. This variety is more of

Lemoine's Deutzia (*Deutzia Lemoinei*) is the hardiest of all the deutzias and excellent for planting in the foreground of shrubbery masses

Flowering shrubs, such as the large flowering mock orange, (*Philadelphia coronarius grandiflorus*) appear ideal with a background of trees.

a continual bloomer than the former, with deep carmine-red flowers and somewhat darker foliage. It seems to blossom almost as profusely in the shade as in full sunlight. It is found very acceptable, therefore, for planting along the north side of buildings or in other partly shaded situations.

Of the many other shrubs worthy of consideration, there are the golden bells or *Forsythias,* whose yellow blossoms are produced even before its leaves in the spring, so early in fact that the flowers are often caught by late freezes; also the yellow flowering currant, *Ribes aureum,* with its sweet fragrant blossoms, and the Japanese Rose, *Rosa rugosa,* with its luxuriant foliage and ever-blooming flowers. There is no trouble about having enough kinds to select from but the difficulty is in limiting the list to the ones that are best. For the home garden maker, it will be wise to stick largely to the old standard sorts.

SHRUBS FOR SPECIAL PURPOSES

Shrubs for Hedges

*Berberis Thunbergii
Thunberg's Barberry
Rosa rugosa
Japanese Rose
Spiræa Vanhouttei
Van Houtt's Spirea or Bridal Wreath
Deutzia Lemoinei
Lemoin's deutzia

Ligustrum amurense
Amur Privet
Lonicera tartarica
Tartarian Honeysuckle
Thuja occidentalis
Arbor-Vitae or White Cedar

Shrubs for Border Planting

a. Low Growing.

Deutzia gracilis
Slender Deutzia
Berberis Thunbergii
Thunberg's Barberry
Symphoricarpos orbiculatus
Coral Berry or *Indian Currant*
Kerria Japonica
Globe Flower or *Corchorus*

Spiræa Bumalda var. Anthony Waterer
Anthony Waterer's Spirea
Spiræa Thunbergii
Thunberg's Spirea
Symphoricarpos albus
Snow Berry

b. Medium Growing.

Ribes ordoratum
Yellow Flowering Currant
Spiræa Vanhouttei
Van Houtt's Spirea or *Bridal Wreath*
Spiræa prunifolia
Plum-leaved Spirea

Rosa rugosa
Japanese Rose
Rhodotypos kerrioides
White Kerria
Deutzia Lemoinei
Lemoin's Deutzia

c. Tall Growing.

Diervilla florida
Rose-colored Weigela
Lonicera Morrowii
Bush Honeysuckle
Forsythia intermedia
Golden Bell
Viburnum (*In Variety*)

Philadelphus coronarius
Mock Orange or Syringa
Lonicera tartarica
Tartarian Honeysuckle
Syringa (*In Variety*)
Lilac
Euonymus americana
Strawberry Bush

Shrubs for Specimen Use

Corinus americanus
Smoke Tree

Euonymus alata
Winged Burning Bush

*The plant names in this bulletin are those adopted by the American Joint Committee on Horticultural Nomenclature.

Chionanthus virginica
White Fringe

Exochorda racemosa
Pearl Bush

Prunus cerasifera Pissardii
Purple-leaved Plum

Prunus communis
Flowering Almond

Caragana arborescens
Siberian Pea Tree

Tamarix (*In Variety*)
Tamarick

Cercis canadensis
Red-bud

Chaenomeles japonica
Japan Quince

Shrubs for Exposed Lake Front

Rosa setigera
Michigan Prairie Rose

Viburnum opulus
High-Bush Cranberry

Tamarix (*In Variety*)

Rhus (*In Variety*)
Sumac

Rhamnus cathartica
Buckthorn

Elæagnus argentea
Silver Thorn

Rosa rugosa
Japanese Rose

Syringa vulgaris
Lilac

Philadelphus coronarius
Mock Orange

Shrubs for Shady Situations

Symphoricarpos albus
Snow Berry

Symphoricarpos orbiculatus
Coral Berry

Calycanthus floridus
Sweet-scented Shrub

Cornus (*In Variety*)
Dogwood

Diervilla hybrida var. Eva Rathke
Weigela Eva Rathke

Viburnum (*In Variety*)

Ligustrum amurense
Amur Privet

Shrubs for Sandy Soils

Rhus canadensis
Fragrant Sumac

Caragana arborescens
Siberian Pea Tree

Forsythia intermedia
Golden Bell

Tamarix (*In Variety*)
Tamarisk

Lonicera tartarica
Tartarian Bush Honeysuckle

Rosa rugosa
Japanese Rose

Rosa setigera
Michigan Prairie Rose

Berberis Thunbergii
Thunberg's Barberry

Rhus glabra
Sumac

Cotinus coggygria
Purple Fringe

Spiræa Vanhouttei
Van Houtt's Spirea

Shrubs for Steep Banks

Rosa setigera
Michigan Prairie Rose
Rhus (*In Variety*)
Sumac
Sorbaria sorbifolia
Ash-leaved Spirea
Spiræa tomentosa
Hardhack

Roses

Hybrid Perpetuals

—For cut flowers.

(Half hardy, requiring some protection over winter)

Frau Karl Druschki (*white*)
Mrs. John Laing (*pink*)
General Jacqueminot (*brilliant crimson*)
Ulrich Brunner (*cherry red*)
Paul Neyron (*deep rose*)
Mrs. R. G. Sharman Crawford (*deep rose-pink*)
John Hopper (*bright rose*)
Marshall P. Wilder (*cherry carmine*)
Prince Camille de Rohan (*deep crimson*)

Hardy Climbing Roses

Baltimore Belle (*white tinted pink*)
Crimson Rambler (*bright crimson*)
Dorothy Perkins (*pink*)
Lady Gay (*rose pink*)
White Dorothy Perkins (*white*)

Roses for Landscape Effect

Rosa rugosa (*Japan rose*)
Rosa setigera (*Michigan Prairie rose*)
Rosa rubiginosa ((*Sweet briar*)
Rosa rubrifolia (*Red-leaved rose*)

Hardy Bush Roses

Austrian Yellow
Persian Yellow
Common Moss
Blanche Moreau (*white*)
Princess Adelaide (*pale rose*)
Gracilis (*deep pink*)

TREES

*"Among all the materials at our disposal for the embellishment of country residences, none are at once so highly ornamental, so indispensable or so easily managed as trees or wood."**

Trees are especially valuable as screens, windbreaks, backgrounds for buildings, for shade and for their own individual beauty in a design. By a natural arrangement of trees in the improvement of the country home grounds, buildings which might otherwise seem bare and bald may be made interesting and often picturesque. They should be disposed around our houses in groups, masses, thickets and as single trees in such a manner as to rival the most beautiful scenery of nature as well as to provide all the comforts and conveniences of a rural home.

In selecting trees for home planting, the following requirements should be considered: namely—form, hardiness, adaptability, rapidity of growth, shade production, freedom from insects and diseases, neatness and general beauty.

In purchasing trees one should obtain healthy, well shaped trees. It is generally a waste of time and money to set poor, deformed trees. Wild trees may be used but they are less likely to withstand the shock of transplanting than those that have been previously transplanted in the nursery. In purchasing shade trees, it is possible to set out trees as large as a foot in diameter but the cost is so great that few can afford to transplant trees of such size. As a rule, smaller trees transplant more successfully. Trees for street planting should be about two inches in diameter and ten to twelve feet in height.

In transplanting trees, as many roots as possible should be preserved as trees with large root systems do much better than those whose roots have been severely pruned.

As the tree is purchased from the nursery, the top or crown is usually already formed. This general shape of the top should be preserved in pruning after transplanting. If the root system has been severely pruned, it will be necessary, however, to cut back the branches of the top to maintain a balance between the roots and foliage, altho it is better to maintain this balance by saving the roots than by sacrificing branches.

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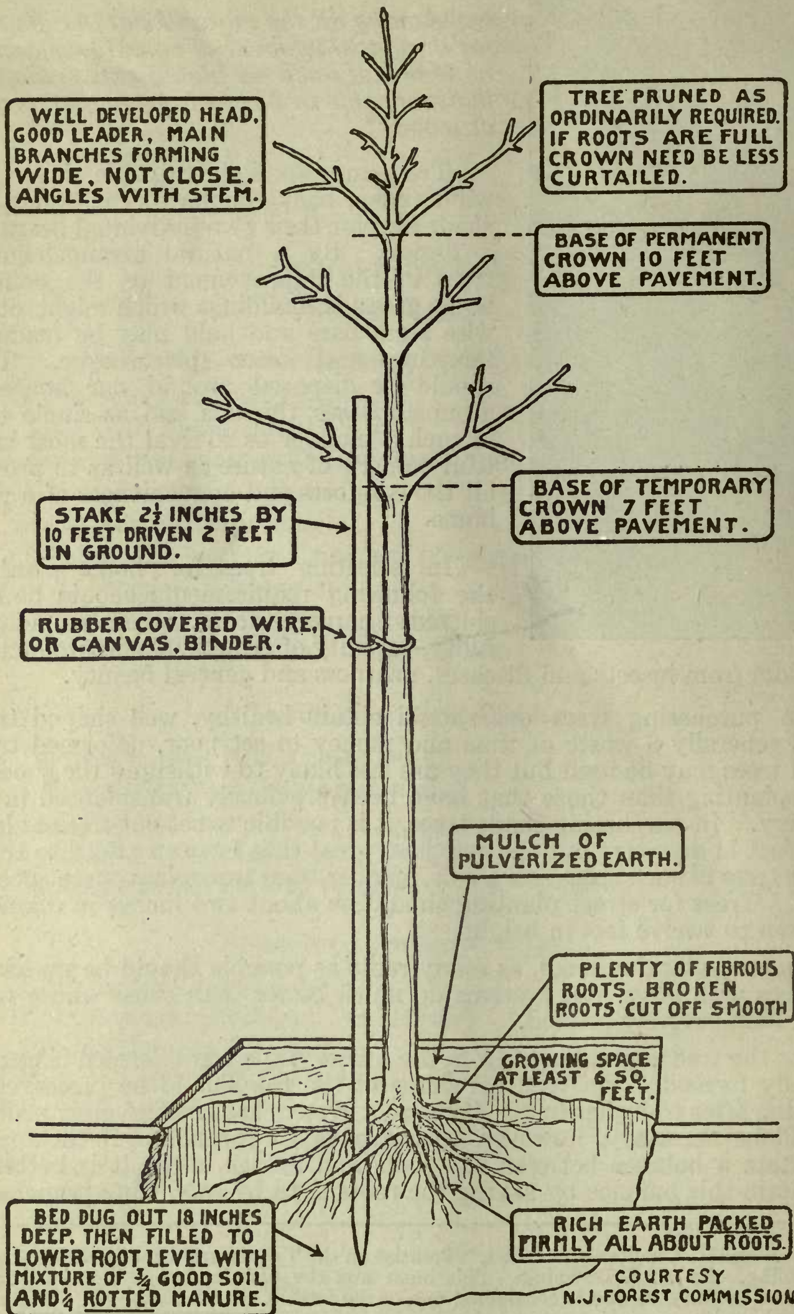
*Section III, Chapter on "Wood," Treatise on the Theory and Practice of Landscape Gardening. By A. J. Downing. This book was the first landscape gardening book published in America and is considered one of the best at the present time. It started a great popular movement toward the development of beautiful home grounds and its author by his many writings and landscape gardening work exerted more influence in the development of American horticulture than probably any other single figure.

Shade Trees.



How to Plant a Tree

During transplanting, the roots of the trees should never be allowed to become dry. If a choice is allowed, transplant a tree on a cloudy day as a bright sun or a dry wind exhausts the stored up moisture. As soon as the trees arrive from the nursery they should be "heeled-in" in moist soil until planting.

Large trees may be transplanted successfully during the dormant period by digging a trench around the roots, some three or four feet from the trunk to retain a large ball of soil with the roots.

In planting the tree, the hole should be dug slightly larger than is necessary to accommodate the roots without bending or twisting them. If the site, as is often the case, is on "made" ground, remove at least a cubic yard of the soil or rubbish and provide as much good loam. In planting the tree, spread a layer of fine mellow soil mixed well with about one-third its bulk of well decomposed stable manure, if available, in the bottom of the hole. Never use fresh manure. The tree should then be planted by packing the fine soil firmly about the roots, setting the tree about two inches deeper in the soil than it stood in the nursery. If the soil is dry at planting time, watering directly after planting will be beneficial as it will help much in packing the soil about the roots and supplying moisture.

After the ball of earth has been frozen, the tree may be transferred to its proper location.

DECIDUOUS TREES

Oaks

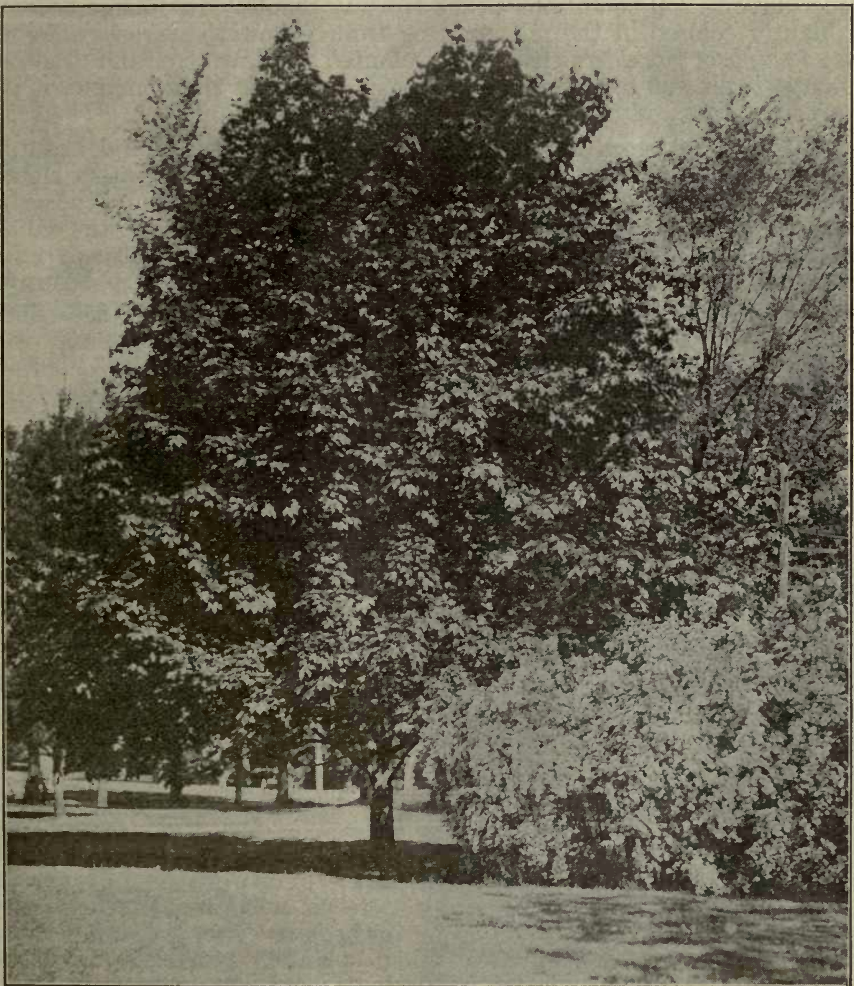
Of all the trees that may be used on the home grounds, the oaks are undoubtedly the best shade trees, for with few exceptions, they are beautiful, long lived and little subject to insects and diseases. They are commonly considered to be slow growing trees but when well cared for the growth of many of them is quite rapid. The *white oak* is probably the best known and one of the longest lived trees. While young, it has an elegant appearance and when old it generally becomes majestic and picturesque. It is especially adapted for lawn planting. The *red oak* seems to be satisfied with a comparatively poor soil, develops a straight sturdy trunk, a symmetrical top and its foliage turns a brilliant color in the fall. It is the most rapid growing of the oaks and well adapted for both lawn and street planting. The *scarlet oak* is much like the red oak, altho it is smaller in size and does well even on poorer soil. Its foliage becomes brilliantly colored in the fall and hence the name. The *pin oak* grows taller and more slender than most other oaks with an unusually straight trunk. The leaves are small and quite persistent through the winter. This tree thrives well upon moist ground but grows well even where the soil is quite dry. It is especially adapted for street planting and also makes a very desirable lawn tree, the foliage being less brilliantly colored than the red oak altho beautiful during all parts of the growing season.

Elms

The American elm is probably the stateliest tree grown in this country. Usually the tree assumes a high, upright spreading form, producing a shade that is not too dense for either lawn or street purposes. As a street tree, it combines more desirable qualities than any other kind altho it grows too large for narrow streets. It prefers a reasonably fertile soil and plenty of moisture, and under these conditions, is a comparatively rapid grower.

MAPLE

No trees have been more widely used for planting the home grounds than the maples, as they are very satisfactory as shade, ornamental or street trees. The *white, silver* or *soft maple* is largely planted because of its rapid growth altho it is a short lived tree, very susceptible to borers and very subject to splitting and breaking. The *Norway maple* is the best tree for streets of moderate width and is a very desirable lawn tree.



The sugar maple (*Acer saccharum*) is one of the best shade trees for the home grounds.

It is adaptable to almost any soil, hardy and little subject to serious insects or diseases. It is one of the first maples to come into foliage in the spring and the last to drop its leaves in the fall although the foliage does not take on such brilliant color effects as the sugar and red maples. The red leaved variety of the Norway maple is an especially attractive tree when properly located on the home grounds. The common *red maple* thrives best on a moist soil and is sometimes used as a street tree although proving more suitable for lawn planting. In the fall, the coloring of the foliage is brilliant and in the spring its blossoms make a very attractive early spring effect. The *sugar maple* is the most widely known and one of the best of all the maples. It is a larger tree than the Norway maple although in many other respects so much like it that the two are often hard to distinguish. It thrives in cool situations and does not do as well under adverse soil conditions as the Norway maple. Its foliage becomes brilliantly colored in the fall, varying from yellow to scarlet. The *ash leaved maple* or *box elder* is frequently planted as a lawn tree and it accommodates itself well to adverse conditions. Like the silver maple, it is a short lived tree and not recommended for general planting.

Beech. The beech makes one of the most attractive and beautiful lawn trees. It requires a rich well-drained soil and grows rather slowly. The tree branches too low to produce a desirable street tree and the crown develops such dense foliage as to cast a heavy shade. During the winter, the light gray tint of the bark produces an excellent landscape effect while in the summer the silvery effect of the foliage is very beautiful. The *American beech* is largely used in this country although there are many ornamental forms of the European species such as the purple-leaved, cut-leaved and drooping beeches that are also popular. In planting upon the lawn, it is well to place these trees well away from the buildings or any spot where sunlight is desired either in winter or summer.

There are many other desirable kinds of deciduous trees that are all valuable under special conditions. Where quick temporary effects are desired the poplars are favorite trees while the attractive and graceful white birches, the golden willows, the stately sycamores or that much over planted catalpa, may sometimes find an appropriate setting in the home planting.

The Norway spruce (*Picea excelsa*) is one of the best evergreens for lawn planting

Evergreens

There are few home grounds where a few ever- greens cannot be advantageously used for producing permanent screens, wind breaks, shelterbelts or hedges. They are very valuable if planted sparingly about the lawn as they contrast well with the deciduous trees and enliven the landscape effects during the winter season. When used too much about the grounds, they are apt to produce a somber gloomy effect. They should never be used near the south or east side of buildings where they might shade them during the winter months. When placed well in the background of shrubs or deciduous trees, they give excellent results.

More spruces have been planted about home grounds than any other kind of evergreen. They are the fastest growing of all evergreens, are very hardy and do well on almost all kinds of soil. For quick effects under average conditions, the spruces are generally the best. They are much used for windbreaks and hedges as well as for planting about the lawn.

The *Norway spruce* is one of the best and most planted of all the spruces. It adapts itself well to any soil and almost any condition. The tree is clean, trim and bright both in summer and winter. As windbreaks upon the farm, it is one of the very best to plant. The trees grow high and thick and will live almost indefinitely. To maintain a thick growth at the base of the tree, it is often necessary to top them. Care must then be taken to prevent the formation and growth of two leaders. The beauty of all evergreens depends upon the preservation of a good healthy growth about the base of the tree whether they are used as hedges, windbreaks to lawn specimens.

The *Colorado blue spruce* is one of the most beautiful of the evergreens. The branches are produced in whorls around the trunk and the foliage is dense and of a bluish color. It thrives in almost any soil and locality, is a vigorous grower and does well in cold exposed situations. These trees are propagated in the nurseries by grafting cions from the finest bluest tree on vigorous seedlings, thus producing trees that are uniformly of a comparatively intense blue color. When seed is planted of this variety, some of the seedlings come true blue while others revert to the green.

White pine is the most valuable variety of pines both for planting about the home and for producing windbreaks or shelter belts. When planted for windbreaks, white pine should be placed further apart than other evergreens as the limbs grow out close to the ground and spread widely. The foliage is softer and finer than most other evergreens. The young trees look trim and neat all the year around while the old specimens are very picturesque.

The *Austrian pine* is a variety that is especially recommended for planting in the middle west. The growth is very dense and the trees grow to a large size. As planted singly on the lawns, the trees produce a beautiful effect while when planted in groups, the dark foliage shows in excellent contrast with spruce or other evergreens.

The *Hemlock* is also a very popular evergreen for lawn planting and for producing hedges. The foliage is very fine, producing a delicate effect and the trees are graceful and usually long lived. They stand shearing well when planted in hedges and will grow in the shade. For planting in groups with other evergreens they are also most excellent. The trees do best with a northern or eastern exposure and when protected from the drying winds. They prefer a moist soil. Sometimes the trees have a tendency to grow quite straggly and should be frequently topped to maintain a dense growth of the lower branches.

Arbor Vitae. These evergreens, commonly known as the white cedars, are usually small growing, formal shaped trees. They are quite different in texture from other evergreens and very beautiful when properly used. The varieties vary much as to their form, size and color of foliage but the pyramidal varieties are most largely used. These may be especially valuable in grouping with other evergreens or in planting as screens or hedges. They stand pruning very well and can be trained to almost any shape. They prefer a moist deep soil but will thrive on any moderately fertile, well drained soil. They may be found growing wild in many of the low moist places in the central western states and if transplanted while still small, will produce excellent specimens.

TREES FOR SPECIAL PURPOSES

a. Street Planting.

Acer saccharum
Sugar Maple
Acer platanoides
Norway Maple
Quercus rubra
Red Oak
Ulmus americana
American Elm
Quercus palustris
Pin Oak
Tilia vulgaris
Linden

b. Trees for Specimen Planting.

Acer platanoides Schwedleri
Purple Norway Maple
Magnolia soulangeana
Soulange's Magnolia
Cratægus coccinea
Scarlet Thorn
Cladrastis lutea
Yellow-Wood
Cornus florida
Flowering Dogwood
Quercus (*In Variety*)
Oak
Populus nigra italica
Lombardy Poplar
Sorbus americana
Mountain Ash
Pyrus (*In Variety*)
Flowering Crabapple
Cercis canadensis
Redbud or Judas Tree
Betula (*In Variety*)
Birch
Prunus cerasifera Pissardii
Purple-leaved Plum
Morus alba pendula
Tea's Weeping Mulberry
Thuja (*In Variety*)
White Cedar
Picea (*In Variety*)
Spruce
Fagus (*In Variety*)
Beech

c. Trees for Exposed Lake Front.

Caragana arborescens
Siberian Pea Tree
Betula pendula
European White Birch
Betula populifolia
American White Birch
Cratægus Oxyacantha
May Thorn

Elæagnus angustifolia
Russian Olive

Pyrus baccata
Flowering Crab

Robinia pseudacacia
Black Locust

Pinus nigra austriaca
Austrian Pine

Pinus sylvestris
Scotch Pine

Picea canadensis
White Spruce

Cratægus Oxyacantha coccinea
Scarlet Thorn

Populus Eugenei
Carolina Poplar

Juniperus communis hibernica
Irish Juniper

Pinus montana Mughus
Dwarf Pine

Sorbus americana
Mountain Ash

Quercus macrocarpa
Mossy Cup Oak

Picea excelsa
Norway Spruce

Trees for Windbreaks

Pinus strobus
White Pine

Picea excelsa
Norway Spruce

Pinus resinosa
Red or Norway Pine

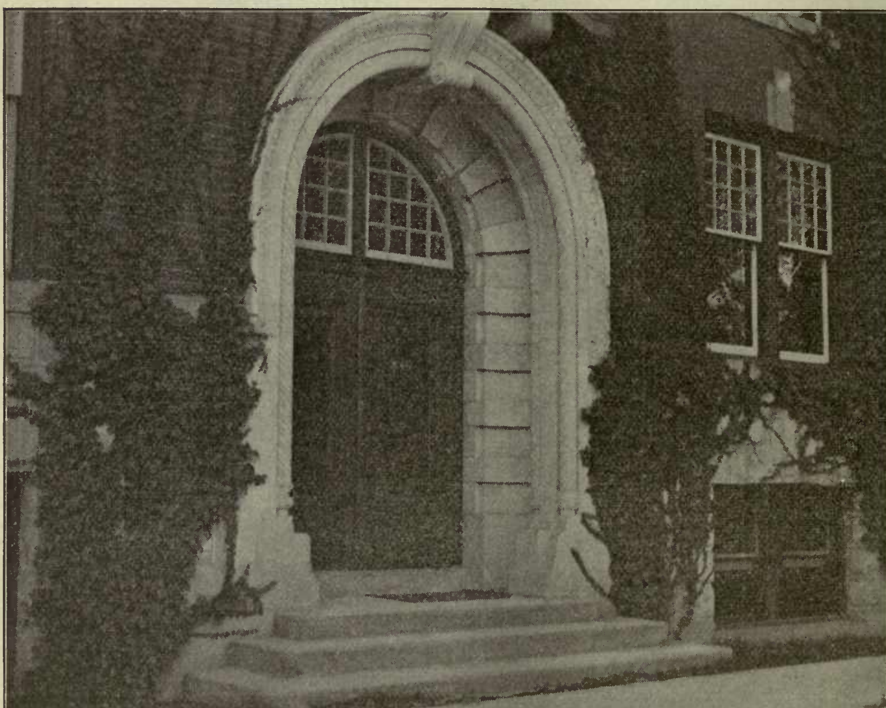
Pinus sylvestris
Scotch Pine

Thuja occidentalis
White Cedar or Arbor-Vitae

VINES

Vines are as essential in harmonizing the house with its surroundings as the trees and shrubs we plant about it. When used in this manner, their principal function is to tone down the stiff, bold angles and bare surfaces of the house, producing a softness in the landscape that could be obtained in no other way. They are also valuable in covering steep banks, walls and fences; in the production of quick screens and in the covering of stumps or conspicuous trunks of trees.

The principal determinants to success in their use consists in selecting the proper places to plant the vines and the most appropriate vine for each place. As one frequently sees them used, they are covering spaces which would be far more beautiful if left open or leaving spaces exposed



Vines should enhance rather than conceal the architecture. The Boston Ivy (*Parthenocissus tricuspidata Veitchii*) is excellent for covering brick or stone work.

which should be covered, thus ruining the architectural features of the building. If correctly used, they should embellish rather than conceal the architecture. Porch columns, cornice lines, corners and angles of buildings should be left open here and there to reveal the form and design of the structure. By planting the less sightly portions and leaving the more beautiful elements of the design exposed, even the most ordinary looking houses may often become very attractive. The style of architecture of the building will largely determine the character of the vine that should be selected to embellish it. The Dutchman's Pipe and Boston Ivy are more suitable for the development of the formal style of treatment than the freer growing vines such as the Clematis or Honeysuckle. Some of the flowering vines that do not produce a dense shade are particularly valuable for draping porch columns and training about windows or along the cornice of a porch. The flowering Clematis, Wistaria and Honeysuckle may often be used in this way, while on porches with a western exposure where a dense shade is desirable, the Virginia Creeper, Bittersweet or some of the vines producing a heavier foliage may be most desirable.

The planting of vines too close to the foundation of buildings is a frequent cause of failure in their development, as the cold wall and dry soil in such a location is not conducive to the growth of vines. It is better to plant them a foot to eighteen inches from the wall where the soil is moist and the roots may develop very vigorously. Exposure is also an important consideration in planting vines. Many of the vines such as Wistaria, Climbing roses and Clematis prefer a southeastern exposure, while the Virginia Creeper, Dutchman's Pipe and the Honeysuckles will thrive in shady places or with a northern exposure. Most vines, however, will flower more freely if given plenty of sunlight. The soil is a very important factor in growing vines successfully. They require a well drained soil, fairly moist and fertile, altho they often survive and struggle along on a poor soil. If the soil is poor, it should be replaced with rich loam, if this can be obtained. Otherwise, the soil should be enriched with well decomposed stable manure or commercial fertilizer, being careful that this material is not allowed to come in direct contact with the roots. After planting, the soil should be kept well cultivated, never allowing it to become hard and dry.

The dust and gases of the cities ruin many of the vines altho certain kinds such as Boston Ivy and Virginia Creeper seem to thrive even under these conditions. These vines, however, should not be allowed to climb upon wooden structures as they are apt to make the house damp and to cause the wood to decay. Vines should be found very acceptable in planting steep banks and thus preventing washing, while for covering bare and unsightly places under trees or over dead stumps, they may be made to produce excellent landscape effects. For covering stone walls, fences, arbors and in countless other ways, vines will be found most effective on the home grounds.

VINES FOR SPECIAL PURPOSES

a. Flowering Vines

Clematis Jackmanii
Purple Clematis

Clematis paniculata
White Flowering Clematis

Campsis radicans
Trumpet Vine

Roses, Wichuraiana Hybrids
Crimson Rambler
Dorothy Perkins.

Wisteria sinensis
Chinese Wisteria

Lonicera japonica Halliana
Hall's Japan Honeysuckle

b. Vines for covering brick, stone and masonry

Parthenocissus tricuspidata Veitchii
Boston Ivy

Parthenocissus quinquefolia Engelmannii
Engelmann's Ampelopsis

Euonymus radicans
Climbing Euonymus

c. Vigorous climbing vines with heavy foliage

Celastrus scandens
Bittersweet

Campsis radicans
Trumpet Vine

Parthenocissus quinquefolia
Virginia Creeper

Lonicera (In Variety)
Honeysuckle

Wisteria sinensis
Chinese Wisteria

Aristolochia macrophylla
Dutchman's Pipe

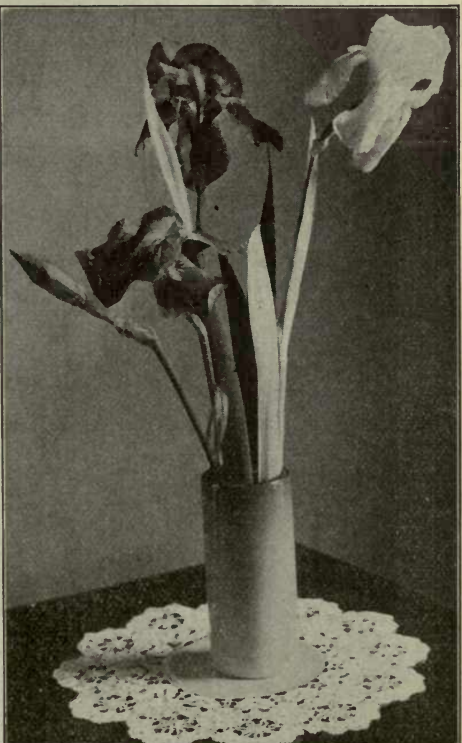
Clematis paniculata
White-flowering Clematis

Speedwell (*Veronica longifolia* var. *subsessilis*), a beautiful perennial that should be more largely planted, producing beautiful spikes of intense lustrous blue color.

HARDY PERENNIALS

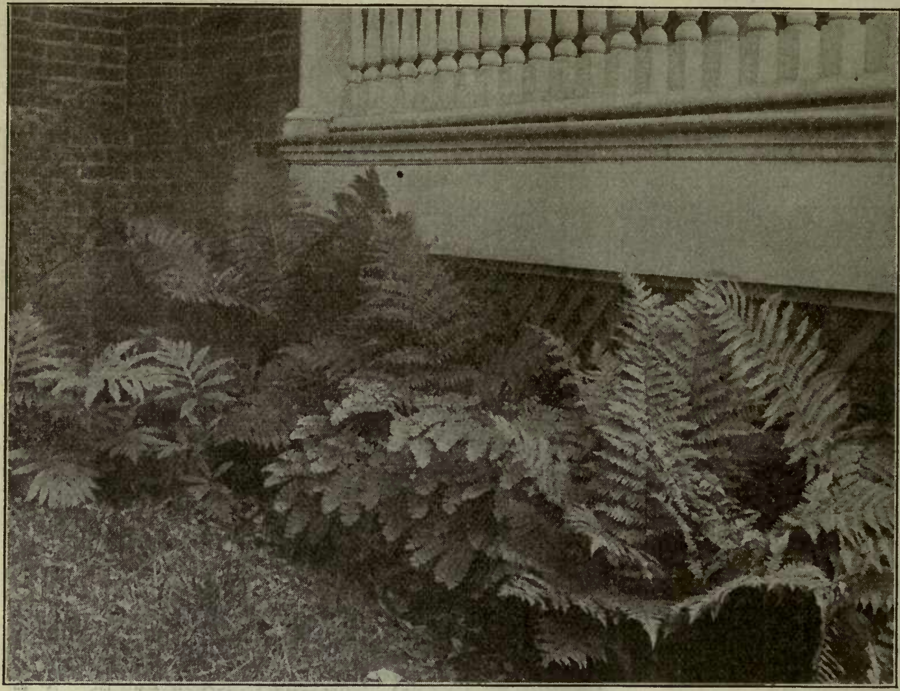
Hardy perennials will always remain a most popular class of flowering plants. There is not a time during the whole flower season in which some hardy perennial is not in bloom, while during the months of July and August, when almost all the woody shrubs have ceased blooming, these plants are mainly depended upon for flower display. They are not fastidious about the soil they grow in altho many have a preference. Under trees or shrubberies, on sloping dry banks, along the borders of ponds or brooks, suitable perennials may be selected that thrive under such conditions. Their ability to thrive with little care makes them a very cheap and desirable class of plants for the home grounds.

Perennials are especially suited for border planting and when placed in front of shrubbery masses they are most effective. They are also very effectively used when planted along garden walks, walls, fences, against buildings and innumerable other places about the home grounds. In planting perennials they should be grouped or naturalistically massed as the effect produced by a colony is more attractive than the effect of a number of varieties scattered aimlessly with few plants of each together. Many of the perennials can be grown from seed. It is best to sow the seed in hotbeds or cold frames very early in the spring and the seedlings may be afterwards transplanted out of doors. Usually, however, they are propagated more easily by division.



The Iris is one of the most satisfactory perennials for border planting and cut flowers.

Of the old time favorites, there are the foxgloves, larkspurs, hollyhocks, sweet-williams and phlox, all so characteristic of the early colonial gardens, that are just as desirable today. There are the columbines, blanket-flowers, coreopsis, peonies and poppies, favorites for their beautiful flowering



Hardy native ferns as a foundation planting along the north side of a porch.

Hollyhocks should be planted against buildings, walls or in front of higher growing plants. They are difficult to transplant but easily grown from seed even on a poor clay soil.

effects. For planting about ponds or upon deep moist soil, there are the iris, forget-me-not, lily-of-the-valley, bee balm, trillium, cardinal flower and the ornamental grasses, while for late summer and fall effects there are the hardy chrysanthemums, golden glow, asters and anemone or wind flower. So from early spring until fall when the ground is finally covered with a blanket of snow, the hardy perennials are lending their color tints to brighten their surroundings.

PERENNIALS FOR SPECIAL PURPOSES

a. Standard Types for General Planting.

Iris germanica
German Iris

Phlox paniculata
Garden Phlox

Paeonia
Peony

Delphinium
Larkspur

Aster
Aster

Rudbeckia laciniata
Golden Glow

Coreopsis lanceolata
Lance-leaved Tickseed

Dianthus barbatus
Sweet William

Aquilegia
Columbine

Chrysanthemum
Chrysanthemum

Althæa rosea
Hollyhock

Purple Loosestrife (*Lythrum Salicaria roseum*), a late summer flowering perennial that delights in a moist soil, planted amid shrubbery,

b. Little Known Perennials That Should Be More Largely Usəd.

Achillea Ptarmica var. Boule de Neige
Ball of Snow
Monarda didyma
Bee Balm
Hosta plantaginea
Day Lily
Gypsophila paniculata
Baby's Breath
Papaver orientale
Oriental Poppy
Phlox subulata
Moss Pink
Hibiscus Moscheutos
Marsh Mallow
Gaillardia aristata
Blanket Flower
Narcissus poeticus
Narcissus
Anemone japonica
Japanese Windflower
Iberis sempervirens
Evergreen Candytuft
Aquilegia formosa hybrids
Columbines
Chrysanthemum coccineum
Feverfew
Lobelia cardinalus
Cardinal Flower
Eulalias (In Variety)
Plume Grasses

CHOICE VARIETIES OF PEONIES

White

Early
Festiva Maxima
Madame de Verneville
Mid-season
Baroness Schroeder
Late
Marie Lemoine
Couronne d'Or

Pink

Early
Delicatissima
Mid-season
Therese
Madame Emile Lemoine
Albert Crousse
Late
Dorchester

Deep Pink

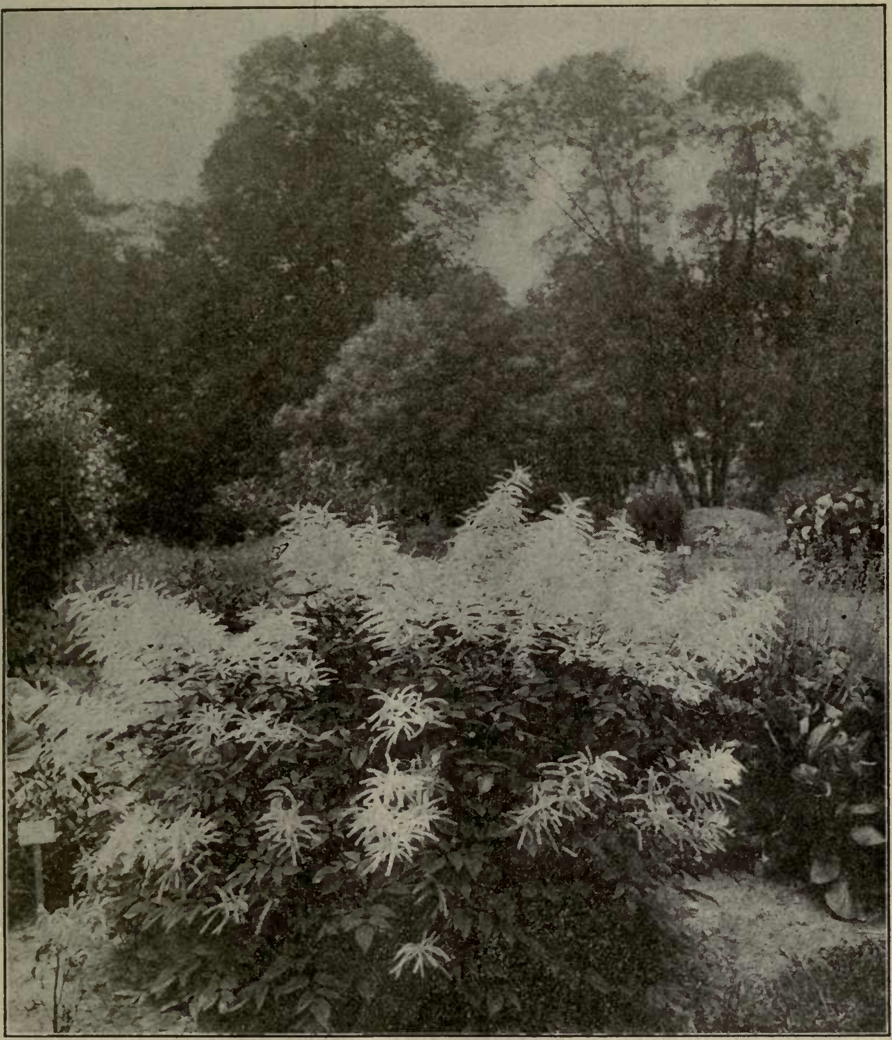
Early
Alexandriana
Mid-season
Modeste Guerin
Late
Livingston
Monsieur Boncharlat Aine

Red

Early
Augustin d'Hour
Mid-season
Felix Crousse
Late
Henry Demay

CHOICE VARIETIES OF PHLOX

Mrs. Jenkins (*early white*)
Fraulein Von Lassburg (*large white*)
Jeanne d'Arc (*late white*)
Bridesmaid (*white, carmine center*)
Henri Murger (*white, carmine center*)
Europa (*white, carmine eye*)
W. C. Egan (*soft pink*)
Selma (*pink, red eye*)
Pantheon (*brilliant rose*)
Rynstrom (*deep salmon pink*)



Goat's-Beard (*Aruncus sylvester*), grown for its large, showy panicles of white flower and does well in a somewhat shady situation.

Siebold (*bright scarlet*)
Rosenberg (*reddish violet with red eye*)
B. Comte (*purple*)

CHOICE VARIETIES OF GERMAN IRIS

Atropurpurea (*purple*)
Fairy (*ivory white, pale violet veins*)
Florentina (*white, tinged with blue*) early
Gracchus (*yellow and crimson*) *early*
King of Iris (*yellow and brown*)
Madame Chereau (*white, tinged blue*)

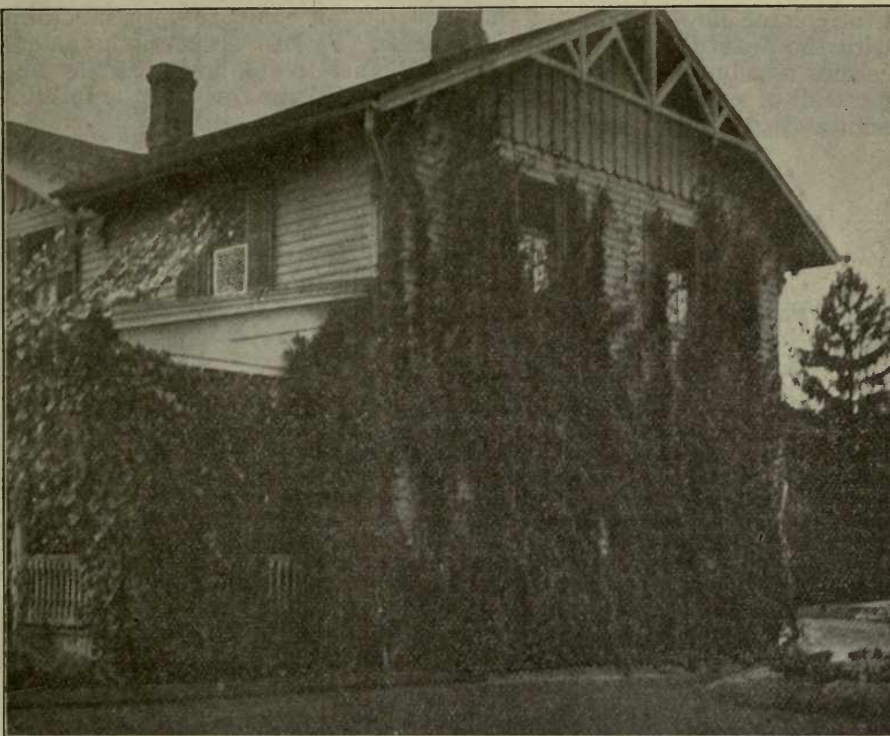
Lupine (*Lupinus polyphyllus*), a very effective hardy perennial on any good garden soil, producing long spikes of deep blue flowers.

Madame Pacquette (*bright rosy claret*) early
Maori King (*rich golden yellow*)
Mrs. H. Darwin (*white, violet veins*) early
Pallida Dalmatica (*lavender, blue*)
Queen of May (*lilac, pink*)
Silver King (*silvery white*) early

ANNUALS

Annuals are always desirable on every home grounds as they are most essential in producing the best and most continuous display of flowers during the summer months. Their great variety and their adaptability to all soils and conditions as well as the many beautiful ways in which they may be used about the home grounds make them almost indispensable. As cut flowers they are the particular favorites of nearly every one and the planting of the home grounds without a few such annuals as sweet peas, asters, pansies, or nasturitums would hardly seem complete.

Annuals are also especially valuable in producing quick effects as well as for enhancing the grounds of the renter or person who has not the means to plant the more expensive perennial or permanent kinds. When planted in the foreground of shrubs or among perennial, annuals are most pleasing but it is an unfortunate mistake to grow annuals in flower beds dotted over the lawn. In the free and natural style of landscape gardening they should be planted in naturalistic beds about the borders of the home grounds and when so arranged, enhance the beauty of the entire



Cobea (*Cobaea scandens*) is one of the most rapid growing of the annual vines and hence excellent for quick effects.

grounds. They may also be appropriately placed as border plantings along garden walks, about the base of buildings or in front of walls or fences.

Annuals are fortunately very easy to grow. Almost all of them may be grown successfully by sowing the seeds of the plants directly in the permanent beds, but usually better plants are obtained by seeding them in hotbeds or cold frames or in boxes of earth in the house, from which they may later be transplanted to the beds. Frequently the plants come into blossom a month earlier when grown in this manner and hence a longer flowering season is obtained.

The kinds of annuals are so numerous that a selection is largely a matter of personal preference. The pansies, if sown in July or August, produce an excellent early spring display, while if seeded indoors in late winter and planted in a partially shaded location, they should bloom continuously during the summer. The sweet alyssum, dusty-miller, candytuft and lobelia make excellent edging plants, while for summer flower displays, nasturtiums, petunias, coxcomb, stocks, verbenia, annual phlox, poppies, salvia, zinnias and balsams are all easily grown and very effective. Portulaca is most accommodating in covering dry sandy banks and the heliotrope, marguerites, stocks and mignonette in furnishing the gardens with their delightful fragrance. For large foliage effects there is nothing to compare with ricinus or castor oil bean, while the large beautiful colored flower spikes of the snap dragon compare very favorably with the beauty of any of the perennials. In late summer, the asters, cosmos and burning-bush add their brilliance to the flower display and most all of such annuals continue to bloom till the frosts of the fall dismantle their robes of beauty.

Annuals Valuable for Cut Flowers

Asters, late branching
Sweet Peas
Cosmos, early flowering
Pansies
Nasturtiums, dwarf
Mignonette
Bachelor Buttons
Zinnias
Snapdragon
Corn Flower
Heliotrope
Stocks
Dianthus

Annuals for Garden Effects

For edgings:

Sweet Alyssum
Lobelia
English Daisy
Dwarf Cockscomb
Dusty Miller
Ageratum
Candytuft

For bedding effects:

Annual Phlox
Verbena
Annual Poppies
Petunia, var. Rosy Morn
African Daisy
Marigold
Balsam
Celosia
Portulaca

Tall growing annuals:

Castor Oil Bean
Sunflower
Cosmos, late

Annual Vines

Cyperus vine
Balloon Vine
Gourd, Ornamental
Climbing Nasturtiums
Scarlet-runner Bean
Wild Cucumber
Morning Glory
Hop Vine
Moon Vine
Cobea

UNIVERSITY OF IDAHO
AGRICULTURAL EXPERIMENT STATION

SCHOOL OF FORESTRY

Tested Forest Trees for Planting in Idaho

By

F. G. MILLER

CIRCULAR NO. 5 JANUARY, 1918

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In accordance with its policy of encouraging the planting of trees in Idaho, by supplying the stock in limited quantities to prospective planters, the School of Forestry offers for sale the following trees at the prices and in the quantities indicated.

COMMON NAME	SCIENTIFIC NAME
Black Locust	*Robinia pseudacacia*
Honey Locust	*Gleditsia triacanthos*
Norway Maple	*Acer platinoides*
Silver Maple	*Acer saccharinum*
Sycamore Maple	*Acer pseudo-platanus*
Sugar Maple	*Acer saccharum*
Box Elder	*Acer negundo*
Black Walnut	*Junglans nigra*
Russian Olive	*Eleagnus angustifolia*
White Ash	*Fraxinus americana*
Mountain Ash	*Pyrus americana*
Red Oak	*Quercus rubra*
Purple Willow Cuttings	*Salix american var. pupurea*
Golden Willow Cuttings	*Salix* sp.
American Willow Cuttings	*Salix americana*
Silver Poplar Cuttings	*Populus alba*
Austrian Pine	*Pinus austriaca*
Jack Pine	*Pinus divaricata*
Scotch Pine	*Pinus sylvestris*
Western Yellow Pine	*Pinus ponderosa*
Western White Pine	*Pinus monticola*
Eastern White Pine	*Pinus strobus*
Douglas Fir	*Pseudotsuga taxifolia*
Blue Spruce	*Picea parryana*
Engelmann Spruce	*Picea engelmanni*
Norway Spruce	*Picea excelsa*
Red Spruce	*Picea rubens*
Concolor Fir	*Abies concolor*
Balsam Fir	*Abies balsamea*
Arborvitae	*Thuja occidentalis*

The following trees may be purchased in the quantities named at 2½ cents each, provided that not more than 300 trees in all may be sent to any one person.

Black Locust, 18 to 24 inches	100
Honey Locust, 10 to 14 inches	30
Norway Maple, 8 to 12 inches	25
Sycamore Maple, 9 to 16 inches	50
Sugar Maple, 8 to 12 inches	50
Silver Maple, 7 to 12 inches	25
Black Walnut, 10 to 13 inches	10
White Ash, 12 to 18 inches	50
Red Oak, 7 to 10 inches	25
Eastern White Pine, 5 to 7 inches	50
Engelmann Spruce, 4 to 6 inches	20
Jack Pine, 7 to 10 inches	25
Western Yellow Pine, 6 to 10 inches	25
Western White Pine, 5 to 7 inches	50
Austrian Pine, 5 to 7 inches	20
Blue Spruce, 4 to 6 inches	20
Norway Spruce, 4 to 6 inches	30
Douglas Fir (Rocky Mt. form), 6 to 8 inches	100
Concolor Fir, 4 to 6 inches	5
Scotch Pine, 4 to 6 inches	20
Russian Olive, 7 to 10 inches	20
Box Elder, 10 to 16 inches	30

The following trees may be purchased in the quantities named at 5 cents each, provided that not more than 300 in all may be sent to any one person.

Norway Maple, 18 to 24 inches	25
Red Oak, 12 to 14 inches	10
Sycamore Maple, 18 to 30 inches	50
Sugar Maple, 14 to 20 inches	20
Silver Maple, 24 to 30 inches	100
White Ash, 18 to 30 inches	100
Scotch Pine, 9 to 12 inches	30
Western White Pine, 12 to 16 inches	50
Eastern White Pine, 10 to 16 inches	50
Concolor Fir, 7 to 11 inches	30
Balsam Fir, 6 to 10 inches	10
Austrian Pine, 12 to 16 inches	50
Blue Spruce, 7 to 10 inches	10
Norway Spruce, 8 to 12 inches	20
Red Spruce, 8 to 10 inches	5
Douglas Fir (Coast form), 9 to 14 inches	5
Douglas Fir (Rocky Mt. form), 8 to 12 inches	40
Cypress, 8 to 12 inches	5
Western Yellow Pine, 8 to 12 inches	10
Russian Olive, 12 to 14 inches	10

A limited number of extra large and fancy trees as follows may be secured at prices per tree and in quantites as listed:

Norway Maple, 5 to 6 ft., 30c	12
Sycamore Maple, 5 to 6 ft., 30c	12
Silver Maple, 5½ to 6½ ft., 15c 12	[illegible]
Sugar Maple, 4½ to 5 ft., 30c 6	5
Norway Maple, 3 to 4 ft., [illegible]c 10	10
Japanese Maple, 3 to 4 ft., 30c	2
White Ash, 4½ to 5 ft., 15c	25
Mountain Ash, 5 to 6 ft., 25c	2
Douglas Fir (Coast form), 18 to 24 in., 20c	5
Arborvitae, 16 to 24 in., 30c	4
Scotch Pine, 2½ to 3½ ft., 20c	25
Jack Pine, 2½ to 3½ ft., 20c	25
Norway Spruce, 14 to 18 in., 10c	25
Norway Spruce, 24 to 30 in., 25c	5
Douglas Fir (Rocky Mt. form), 18 to 24 in., 20c	10

In lots of 1000 or more, the School of Forestry will furnish the following species at 1 cent each:

White Ash, 12 to 18 inches
Western White Pine, 5 to 7 inches.
Douglas Fir (Rocky Mt. form), 6 to 8 inches
Scotch Pine, 4 to 6 in.

Cuttings will be furnished in quantities and at prices per cutting listed below:

American Willow Cuttings, 200, ¾c
Purple Willow Cuttings, 200, ¾c
Golden Willow Cuttings, 20, 1c
Silver Poplar Cuttings, 20, 1c

All the trees offered have been thoroly tested, are choice stock, and will be shipped under an inspection tag. The prices stated include packing and drayage but not express charges. All trees must be shipped by express, so *do not fail to give your express office. The money must accompany all orders.* It is desirable that all orders be received by March 1, so that they may be filled before the season is too far advanced.

SUGGESTIONS FOR MAKING YOUR SELECTION

For southern Idaho where the trees are to be grown without irrigation, and where the annual precipitation is not less than 15 inches, we recommend Black Locust, Russian Olive, Jack Pine, Scotch Pine, Western Yellow Pine and Douglas Fir (Rocky Mountain Form). If the yearly precipitation is 20 inches or more, to the above may be added Honey Locust, Norway Maple, Austrian Pine, and Blue Spruce.

Where the annual precepitation is 25 inches or more, or if the trees are to be grown under irrigation, any of the trees we offer may be planted in either the southern or the northern part of the state, within reasonable altitudes, *e.g.*, up to 4000 or 5000 feet. The spruces offered will succeed in elevations up to 7000 feet.

For narrow windbreaks, the evergreens are especially suited, since they hold their leaves the year round. If the windbreak is to be several rods in width, the hardwoods will prove effective, and will grow considerably faster. Willows are especially adapted to windbreak formation.

In woodlot planting, no tree is so generally adapted to Idaho conditions as the Black Locust. Its rapid growth and the durability of its wood in contact with the soil, make this tree one of the most valuable that can be grown for fence posts. White Ash and Red Oak are other hardwoods that may be recommended for the establishment of woodlots. Among the conifers, the pines and Douglas Fir are well adapted to this purpose. While both the Rocky Mountain and Coast forms of Douglass Fir are grown in our nurseries, the Coast form is recommended for only the northern part of Idaho. The Rocky Mountain form will succeed thruout the state.

The selection of trees for ornamental planting is largely a matter of individual taste. Any tree at its best is highly ornamental. Pleasing effects are more dependent upon arrangement than upon the choice of trees, but it is beyond the scope of this circular to enter into a discussion of this interesting phase of ornamental planting. Suffice it to say that there is little chance for mistake in choosing for ornamental purposes any of the trees offered, provided local conditions of soil, moisture, and altitude are right. If in doubt, write us.

TIME TO PLANT

The trees should be planted as soon as the soil is readily tillable, the earlier the better, after the ground is in shape.

HOW TO HANDLE THE STOCK

Immediately on the arrival of the trees at your express office, they should be called for and, if possible, planted the same day. If necessary to hold them over, they should be unwrapped and heeled-in. This is done by digging a trench, placing the trees in it, and covering the roots with fresh, moist, earth. When planting, you should remove from the trench but a few trees at a time. This is especially important with evergreens, as the exposure of the roots for two or three minutes to the drying effects of the sun and wind may kill them. The soil for the planting site should have as good preparation before planting as you would give a garden.

In planting, the holes should be deep enough so that when the trees are in place, they will stand a little deeper than they stood in the nursery row. When setting the tree, the roots should be spread out as nearly as possible in their natural position. Use the hands in replacing the first few layers of dirt, and see that it is pressed carefully and firmly about the roots.

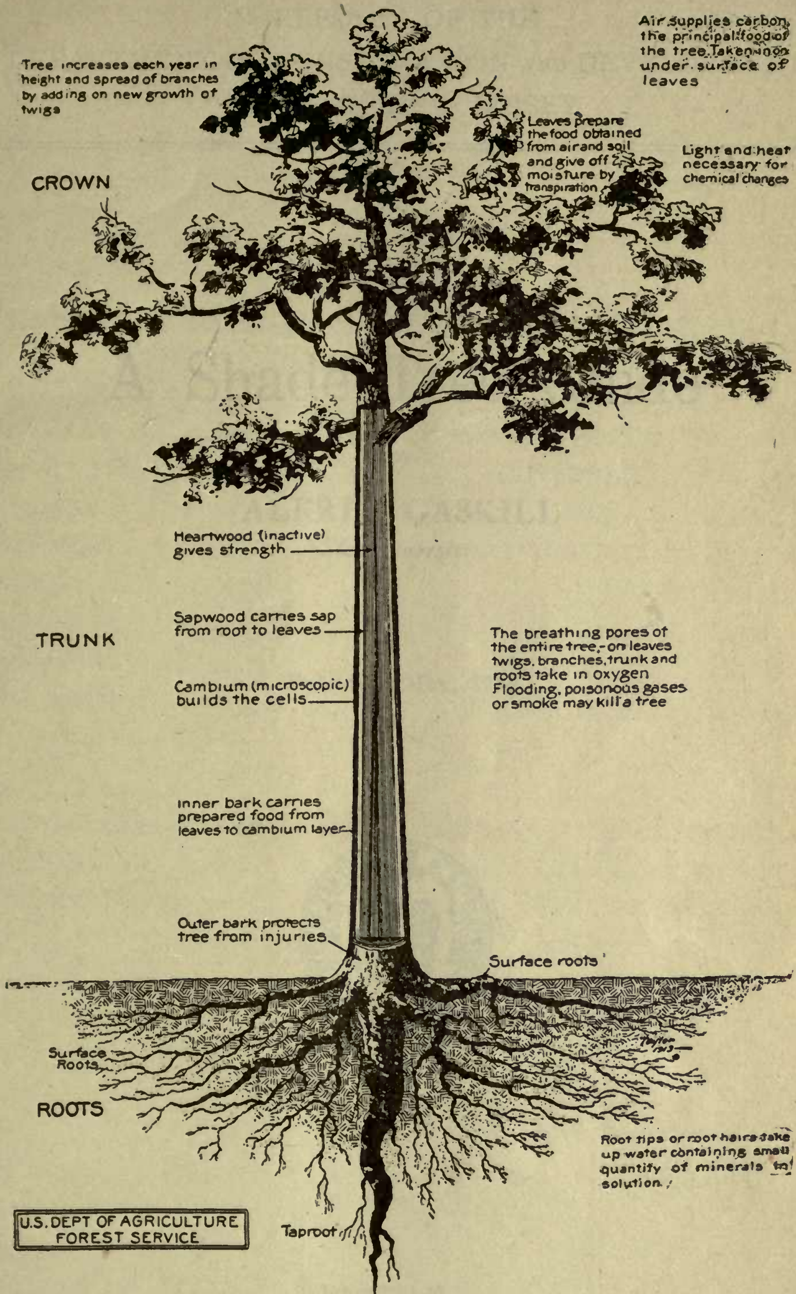
In the matter of spacing the tendency in ornamental planting is to plant too close. The object sought here is symmetrically formed trees, even in late life, which cannot be the case if the trees are crowded. For ornamental purposes, ordinarily, the trees should not be closer than 40 feet apart, or rarely 30 feet, unless the planting be along the roadside where the spacing may be 20 to 25 feet.

CARE AND CULTIVATION

Whatever the purpose of the planting, whether for woodlots, shelter-belts, or ornament, the trees must be carefully cultivated indefinitely. This is especially important the first several years. Level surface cultivation should be the practice: Live stock, too, must be rigidly excluded.

Address all orders to

F. G. MILLER,
Idaho Experiment Station,
School of Forestry,
Moscow, Idaho.



HOW THE TREE GROWS

The buds, root tips and cambium layer are the growing parts of the tree. Water containing a small quantity of minerals in solution is absorbed by the roots carried up through the sapwood to the leaves and there combined with carbon from the air to make food. This food is carried by the inner bark to all growing parts of the tree, even down to the root-tips.

REPORTS OF THE
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
STATE OF NEW JERSEY

A Shade Tree Guide

by

ALFRED GASKILL

State Forester

Published May, 1918

Union Hill, N. J.
HUDSON PRINTING COMPANY.

1918

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OFFICE, STATE HOUSE ANNEX, TRENTON.

Contents.

Illustrations.

A Shade Tree Guide

This bulletin will be helpful to municipal authorities and to those who wish to maintain vigorous, attractive trees on their properties. Few people realize that any tree standing beside a sidewalk, or even on a lawn, is out of its element (the forest), and that the strains and dangers to which it is subject must be counteracted in every way possible. The advice given refers particularly to New Jersey; it is applicable to most of the eastern United States.

The value of shade trees. Tho it is now well established that a shade tree has a value beyond that of its wood, or the cost of planting a new one, and that neither individuals nor public service agencies can injure one without becoming liable for damages, it is advisable always to avoid such troubles.

Street trees and lawn trees. It is needful to distinguish between street trees and lawn trees because only a few deciduous species, and no evergreens, can be maintained on narrow paved ways, whereas a lawn admits a variety of trees and shrubs, deciduous and evergreen, that is limited only by space and climatic conditions. On streets and lawns close to the sea the available kinds of trees are few, and extreme care in their selection and nurture is required.

Street Trees

Shade Tree Commission. It is always advisable to have street trees under the control of a Shade Tree Commission, such as is maintained in many communities in New Jersey and in several other states. These organizations can secure better results than individuals.

Old trees. An established tree, even of poor kind, is better than a newly planted one. Unless an old tree is decrepit or a nuisance it should be saved until a new one can be started to take its place. If young trees are planted between old ones before the latter have to be removed there will be less objection to taking away the undesirable ones than there may be if gaps are created. (Fig. 2.)

What to plant. In the choice of trees for street planting there is no room for experiments; one must select a kind that will live, and give satisfaction, for many years under fixed, and usually unfavorable, conditions. It is generally agreed that an acceptable street tree must be of form suited to the space, hardy and not subject to insects or disease, fairly rapid in growth, a good shade producer, and neat in that it drops no objectionable litter. The list of available trees is practically limited to the following. In most cases choice should be restricted to the kinds indicated by *italic* type.

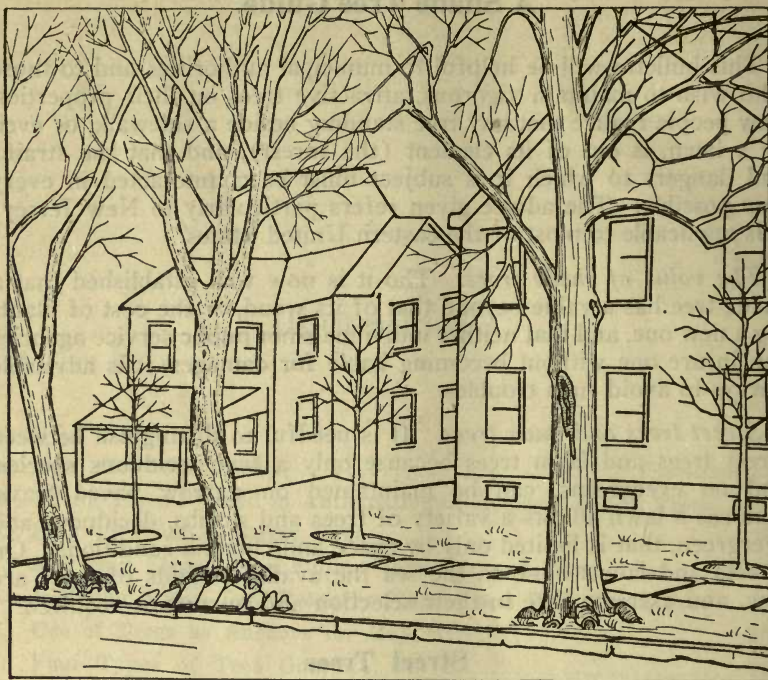

Fig. 2. Young Trees Planted on an Inside Line in Anticipation of the Removal of Decadent Old Trees on the Curbing.

The Best Trees for City Streets

Narrow Streets. (less than 60 feet wide between building lines.)	**Average Streets.** (60 to 90 feet wide between building lines.)	**Wide Streets.** (over 90 feet wide between building lines.)
Ginkgo	*Scarlet Oak*	*White Elm*
Norway Maple	*Ginkgo*	*Red Oak*
Hackberry	*Norway Maple*	*Sycamore*
Green Ash	*Red Oak*	*Tulip Poplar*
Red Gum	*Sycamore*	Sugar Maple
Red Maple	*Hackberry*	White Oak
Honey Locust	Red Maple	Basswood
	Pin Oak	Red Gum
	Basswood	Scarlet Oak
	White Ash	Ailanthus
	Red Gum	
	Sugar Maple	
	Honey Locust	
	Horse Chestnut	

The tree to be planted will be more likely to thrive if it comes from a reputable nursery than if it grew wild, because nursery culture induces the development of compact root systems and lessens the risk of moving. The larger the mass of small feeding roots that is taken up, and the more earth that is moved with them, the quicker and better will the tree establish itself. Red Gum has very tender roots and is rarely planted successfully unless it is moved with a "ball" the same as an evergreen (p. 10). A tree of any kind should be healthy, symmetrical, and, as a rule, have a breast-high diameter of between 2 and 3 inches and a height of about 12 feet.

To insure the necessary headroom for street traffic no tree that forks at less than 10 feet above the ground should be used, and no branch whose base is less than 7 feet above the pavement should be retained. Contrary to a common belief, the branches of a tree remain fixed forever at one height above the ground; their bases are not carried upward by growth. (Frontispiece.)

Trees to avoid. Silver Maples, Poplars and Willows are rapid growers but short lived, easily broken and given to producing surface roots and suckers. *Locust* is thin foliaged and subject to a boring insect. *Nut trees* invite injury by their fruit.

Location. If conditions permit it, trees usually should be planted inside the sidewalk rather than close to the curb. There they are less subject to injury, their roots have more room, their crowns are less in contact with overhead wires, and they shade the houses better. Wherever space permits it is well to depart from straight lines.

Intervals. Street trees usually are planted too closely together. The proper distance will be determined to some extent by the species, the width of the sidewalk and the front width of the building lots. A safe rule is so to space the trees that their crowns will never interfere, but have considerable air and light between. Thirty feet is a minimum interval; fifty feet or more is better.

When to plant. Trees can be planted at any time when they are not in leaf. They are most apt to succeed if planted in spring, as soon as the frost is out of the ground. A cloudy, quiet day is better than a bright or windy one. (See p. 10.)

How to plant. Dig the hole before the tree arrives and follow instructions given in figure 3. If the local soil is poor make the hole at least two feet larger and one foot deeper than is required. Remove the poor soil and bring good, rich loam. Cut off all broken roots but save as many as possible of the small fibrous ones. Be careful that the roots do not dry out. Put enriched earth in the hole until the tree when standing upon it will be two inches lower, not more, than it stood in the nursery. Hold the tree upright, fill in the mixed soil and fertilizer and compact it firmly about the roots.

Use plenty of water to settle the earth and be sure that every root is firmly embedded. Many newly planted trees die because their roots are left in air pockets. When all is done rake the surface to check evaporation. Successful tree planting depends upon care at every point—a vigorous tree with plenty of good roots, an ample bed of good soil for root growth and careful planting are of prime importance. Then frequent watering, occasional cultivating, and fertilizer once a year. If these things are ignored a tree may live but will never thrive.

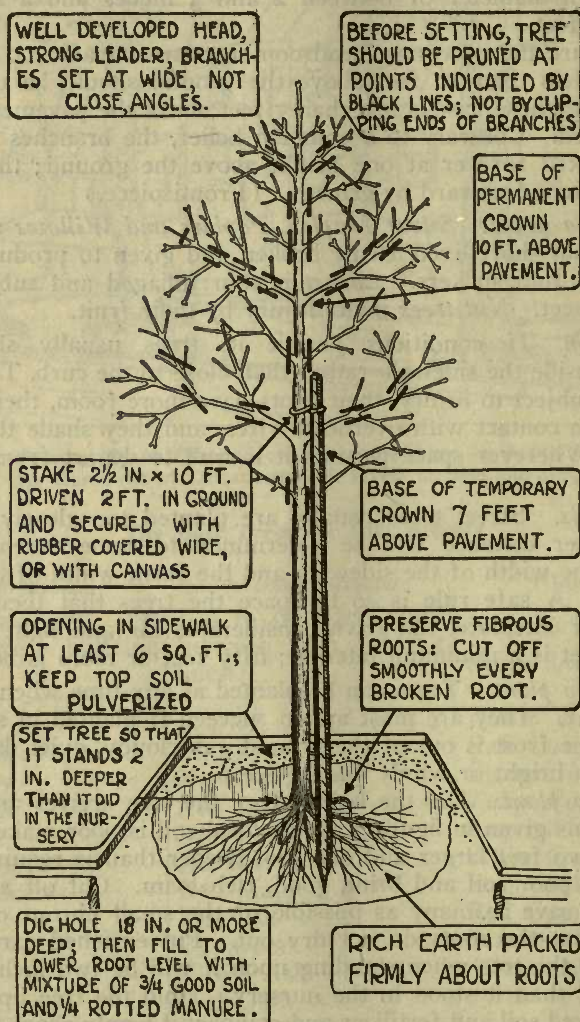

Fig. 3. How to Plant a Street Tree. It is Important to Observe Every Point Indicated in the Diagram.

How to keep trees healthy. Any tree will resist insects and disease, and will recover from injury much more readily if it is vigorous and healthy than if it is weak. Observe the following rules: Never let a sidewalk be laid closely about a tree; a surface of bare earth (footing) at least 2 by 3 feet, preferably 4 by 8 feet, should be kept (figs. 2, 3, 5); when a tree is fully established this may be grassed over, tho it is advisable to keep it open. Once a year work a little fertilizer into this open space and water it at intervals as directed at page 13.

Fig. 4. A Young Street Tree. Failing Thru Lack of Care.—Of Poor Form, with Branches too Low, It is Crowded in a Brick Pavement, Has no Stake and Only a Short, Frail Guard.

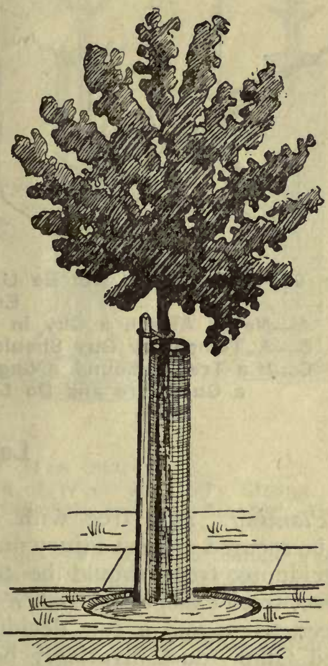

Fig. 5. A Young Street Tree of Good Form, Properly Planted and Well Cared For.—Guard, Stake, Footing as They Should Be.

If a young tree is exposed to winds or other strain, keep it firm and upright by means of a stout stake to which the stem is secured in such fashion that it will not be rubbed (fig. 5). Unless the tree is so placed that it cannot be gnawed by horses maintain a stout guard about it (figs. 5, 7). Apart from the pruning required when a tree is planted most trees should be allowed to develop naturally. Pruning as frequently practiced in butchery. (See p. 19 and fig. 12.) Allow no tree to support a guy wire except under necessity. In that case, and only if the tree is strong and healthy, let an eye bolt be driven into the heart, or all the way thru, and the guy wire attached to that; no form of band should be tolerated except temporarily in an emergency.

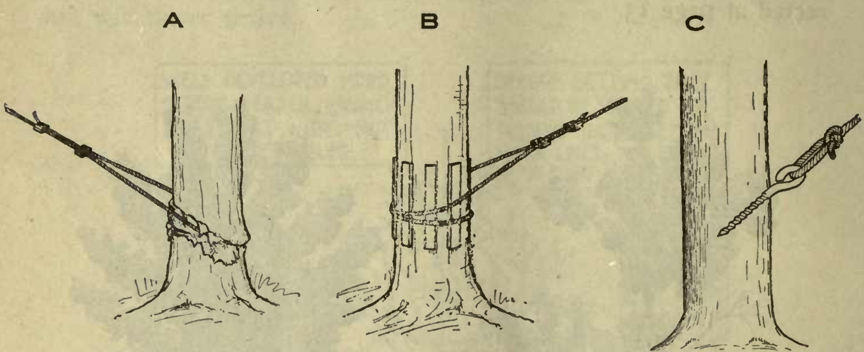

Fig. 6. Trees Should Not Be Used to Anchor Guy Wires Except in an Emergency.
A—Never Attach a Guy in This Way.
B—A Temporary Guy Should Have Wood Blocks Under the Wire.
C—If a Tree is Sound, a Lag Screw Driven Into the Heart Will Hold a Guy Wire and Do Least Harm.

Lawn Trees

Planting. Any tree with ample space about it requires only to be secured against injury and to be supplied with food and water. Deciduous trees should be planted exactly as recommended for street trees except that stakes and guards are rarely required. Evergreen trees, and a few deciduous species with succulent roots, as Red Gum, must invariably be moved from the nursery with the roots embedded in a ball of earth. When the hole has been prepared and good earth supplied, loosen the bagging that encloses the ball and set the tree with the earth still about its roots.

As a rule lawn trees, like street trees, do best when planted in early spring, tho evergreens allow greater latitude and often thrive when moved in August. When that is done it is important to guard them against strong winds in winter.

Lawn trees ordinarily require less care than street trees, but a circle at least 3 feet in diameter should be kept without sod about the base of a newly planted tree of whatever kind, and the soil within it worked frequently, until the tree is firmly established. Grass may then be allowed to grow, altho it is advisable to maintain the opening continually as a guard against injuring the base of the tree by the lawn mower.

"Wells" and mounds. If the level of the ground about an old tree is changed a "well" must be built in a fill to keep the soil away from the trunk and to avoid smothering the roots, or a mound left on a cut to prevent exposure.

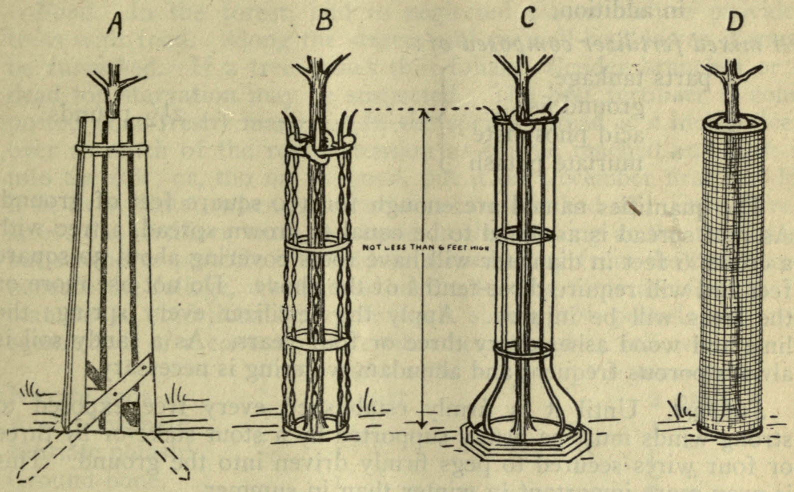

Fig. 7. Four Types of Tree Guards.

A—Standard in Washington, D. C. Made of Wood and Very Strong. It Also Serves as a Support, but is Unsightly and Not Cleanly. Cost About $1.50.

B—Made of Ornamental Fence Wire. Too Frail to be of Much Value as a Guard and of None as a Support. Cost About $1.00.

C—Made of Heavy Wrought Iron. Is Attractive, Strong and Durable. Cost With Grill About $10.

D—Made of 1-2 inch Galvanized Iron Screen, with Rubber Hose Buffer at Top. Harbors Insects and Must be Supplemented by a Supporting Stake, but Very Popular. Cost About 80 Cents.

Seashore Trees

Whether along the streets or upon lawns, trees near the ocean have to contend with poverty of soil, deficient soil moisture and strong winds, those of winter in particular. It is useless to try to maintain trees where they can be reached by ocean spray—say within 200 feet of high water. Beyond that point it is simply a question of choosing hardy species and strengthening sterile soil.

Fertilizer. It is not necessary to transport inland soil, the poorest sand may be treated thus:

Add to the native soil:

Oyster shell lime	9	pounds
Wood ashes	2½	"
Composted (not fresh) manure	50	"

Or as a substitute for the manure, *not* in addition,

A mixed fertilizer composed of:

2 parts tankage 2 " ground fish 3 " acid phosphate 3 " muriate potash	2½ pounds

The quantities named are enough for 100 square feet of ground. As root spread is assumed to be equal to crown spread, a tree with a crown 6 feet in diameter will have roots covering about 30 square feet and will require three-tenths of the above. Do not use more or the trees will be injured. Apply the fertilizer every spring; the lime and wood ashes every three or four years. As a sandy soil is always porous frequent and abundant watering is necessary.

Support. Until it is firmly established every tree exposed to strong winds must be firmly supported by a stout stake or by three or four wires secured to pegs firmly driven into the ground. This is even more important in winter than in summer.

What to plant. For street planting the choice of species should be limited to sycamore, ailanthus, pin oak, scarlet oak, red oak, hackberry, honey locust, red maple, and in most situations preference given in the order named, altho it is not advisable that too many of the same kind be used. Upon lawns oaks and pines, with various hardy shrubs, are to be preferred to the firs, spruces and cypresses, and the many deciduous trees, that are available inland.

Nourishment

More trees suffer from starvation than from anything else. On lawns as on sidewalks a tree's natural food (fallen leaves, etc.), is taken away, water is denied and both rain and air are excluded by close pavements, or by sod. The consequent weakened condition induces disease and insect attack. Don't plant a tree unless it can have at least 6 square feet of open soil at its base. For several years after a tree is planted this is imperative, afterwards sod, not paving, may be tolerated. Frequent working of the surface soil, as in any garden, will tend to keep a tree in good condition.

Water. Street trees require more water than lawn trees because their roots are apt to be restricted and because sun-heated pavements and buildings increase transpiration. A good rule is to see that the ground about a tree is soaked once a week. If rain fails use the hose or a pail. Sprinkling, tho done frequently, is only a little better than nothing. Too frequent soaking will exclude the air and cause the roots to rot. When the ground has dried after a wetting, rake the surface to check evaporation. If the ground does not dry within an hour too much water has been applied.

Food. In the forest, and in neglected places, nature provides trees with food. Along the streets and on well-kept lawns it must be furnished. If a tree shows thin foliage, slender branches or a dead top starvation may be suspected. The best fertilizer is composted (not fresh) manure. In the spring spread it 2 inches deep over as much of the root extension as can be reached and fork it into the soil; or, tho not so good, put it on December first and let it lie over winter, when what remains can be raked off. On a paved street the fertilizer must be placed in the opening at the tree base, but whenever possible it should be spread away from the trunk and beneath the foliage, where most of the feeding roots are found. If manure is objectionable, apply each spring 1½ pounds per 100 square feet of a commercial fertilizer composed as follows:

	For light soils.	For heavy soils.
Nitrate soda	1 part	2 parts
Acid phosphate	1 "	3 "
Muriate potash[1]	1 "	1 "
Ground bone	1 "	2 "

Distribute the fertilizer evenly and mix it with the soil; be careful not to use an excess else the tree roots may be burned.

If it is desired simply to sustain an old tree without inducing growth, use a small quantity of manure, or from 1 to 1½ pounds per 100 square feet of a mixture containing 1 part nitrate soda, 1 part bone meal, 5 parts acid phosphate.

Pruning

Trees need to be pruned only (1) when they are transplanted; (2) when they interfere with other trees or structures; (3) when they are weakened by decay or by overgrowth. Much of the pruning done by so-called experts is useless or even harmful. Most trees should be allowed to develop according to their natural habit. When pruning is permissible the following rules apply.

When transplanted, a tree must have its crown cut back to balance the inevitable loss of roots. See figure 3, and observe that useless interior branches are removed entirely.

Form. If a tree grows one sided, if its branches interfere with a building, or with another tree, curtail or cut out entirely the aggres-

[1]Wood ashes may be substituted at the rate of 10 pounds to 1 pound of muriate potash.

sive member. With few exceptions trimming the ends of branches is wrong and cutting off the whole top is butchery.

Branches which hang too low should not be trimmed, but cut back to the trunk or main branch. If branches grow so that they interfere with electric wires, either have the wires lowered, or remove entirely all but the three or four most vigorous shoots and stimulate the tree to carry a crown above the wires. (See p. 19.) For treatment of heavy limbs see Injuries, page 15.

Vigor. If a tree is so weakened that dry branches appear, cut out all the dead wood, and such of the living members as is necessary to make the tree shapely. If lack of vigor is shown by drooping foliage and the crown is very dense (as is common in Norway maples and sugar maples), relief will be given by removing a quarter or a third of the foliage. This should be done, not by cutting off the extremities, but by taking out interior branches entire (figs. 8, 9). When done skilfully the appearance of a tree as well as its strength is improved. After pruning for vigor a tree should always be well fertilized and watered.

Fig. 8. Diagram, from a Photograph, of a Norway Maple Showing the very Dense Crown Common with this Species. The Foliage Produced Makes a Heavy Draft upon the Soil Fertility and Water and Frequently Leads to Wilting.

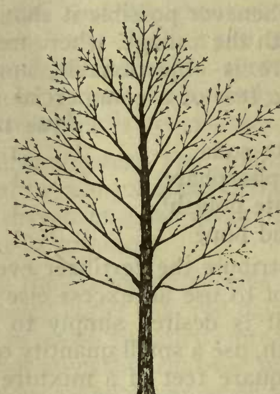

Fig. 9. The Same Norway Maple as that Shown in Fig. 8 with Superfluous Branches Removed by an Interior Pruning. This Preserves the Natural Form of the Crown and a Frame that will Produce as much Foliage as is Desirable.

Covering cuts. Unless it is properly treated every break in the bark of a tree affords entrance to disease germs. In practice clean cuts less than an inch in diameter are ignored; every larger wound should be coated with an antiseptic. The most practical is creosote followed by coal tar. Tar alone is often used, but does not penetrate deep enough to give best results. Creosote is a dark oil and can be applied with a brush. Tar should be made liquid by heat and applied in the same way. It is advisable to avoid covering the cambium.

Time to prune. Pruning may be done when it is most convenient unless "bleeding" (p. 21) is induced. That is most apt to occur in early spring or early fall. Late winter is usually best because there is then little sap movement and the absence of foliage makes the work easier. (See p. 8.)

Injuries

Broken limbs. Every broken limb should be cleared away promptly by a cut, or succession of cuts, that leave a wound which will heal quickly. Small limbs can be taken off by a single cut, larger ones require three, as indicated at B, figure 11. It is important to use a sharp saw, make the final cut close to the larger member and be careful that the bark at the bottom is not torn. A wound shaped as indicated at RIGHT, figure 10, will heal most quickly; one shaped as indicated at WRONG will heal more slowly at the top because the arch is flatter, and very slowly at the bottom because the bark is torn away. A stub as at C, figure 11, should never be left. The face of the wound should be treated as directed on page 14. Cement will do harm rather than good.

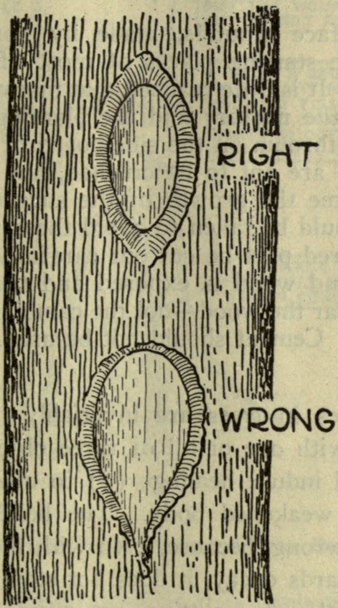

Fig. 10. Cut Marked RIGHT is Healing Properly and Quickly. Cut Marked WRONG is Healing Slowly, and Not at All at the Bottom, Where the Bark is Torn. Every Wound on a Tree that Can be so Treated, Whether a Mere Bark Bruise or the Stub of a Severed Limb, Should be Trimmed to a Long, Regular Oval.

Frost cracks, sun cracks, and *winter kill.* Extremely cold weather, especially when it follows a late growing season, sometimes freezes the water in the outer cells of a tree stem and causes a long crack. Thin-barked species, like sycamore and horse chestnut, are most susceptible and any tree on a street, exposed as it must be, is apt to suffer. *Sun cracks* have the same appearance but are caused by excessive heat, often reflected from a white pavement or wall. In large trees such cracks usually close again with warmer weather and no serious harm is done, but the wood does not unite and a scar is left. On small trees the crack is apt to persist until new growth covers it. There is no practical preventive, and no remedy other than helping nature by every care to heal the wound. This can be hastened by treating the crack with antiseptic, and keeping it from reopening by strong staples, driven in warm weather when the gap is narrowest. *"Winter kill"* occurs when the vital parts of a tree trunk are frozen and ruptured in a *horizontal plane* by the formation of ice about its base. There is no remedy, but the trouble can usually be avoided by having the ground slope away from the foot of a tree on all sides so that no water can collect there. "Winter kill" is common on the terminal shoots of many trees and shrubs and rarely does permanent harm.

Abrasions. Surface wounds, made by horses, lawn mowers, blows, etc., are the starting places of most of the decay that destroys shade trees. It is little realized that many serious tree wounds originate between the nursery and the planting site. If the trunk of a young tree is thrown on the side-board of a wagon the tender bark and cambium are apt to be crushed, and tho the injury may not show at the time the growth of the surrounding parts reveals it. Every care should be taken to avoid these injuries. When one occurs let the injured part be cut out carefully with a sharp knife or chisel until sound wood is exposed and the edges left smooth. Then sterilize and tar the wood—not the cambium or bark, and leave the rest to nature. Cement should not be used. (See F and H, fig. 11.)

Cavities. Cavities in trees are invariably the result of decay. They are treated with one or all of three objects in view: (1) to stop the decay and induce healing; (2) to hide an unsightly part; (3) to support a weakened body. The belief that every cavity should be filled is wrong, because, even with the best workmanship, a filling merely retards decay, it does not stop it. The best rule is to clean a cavity thoroly—cutting out all decayed tissue with a gouge and mallet until sound heart wood is exposed. If the cavity will not hold rain water, or the wound is not unsightly, trim the edges neatly, treat the wood surface and stop.

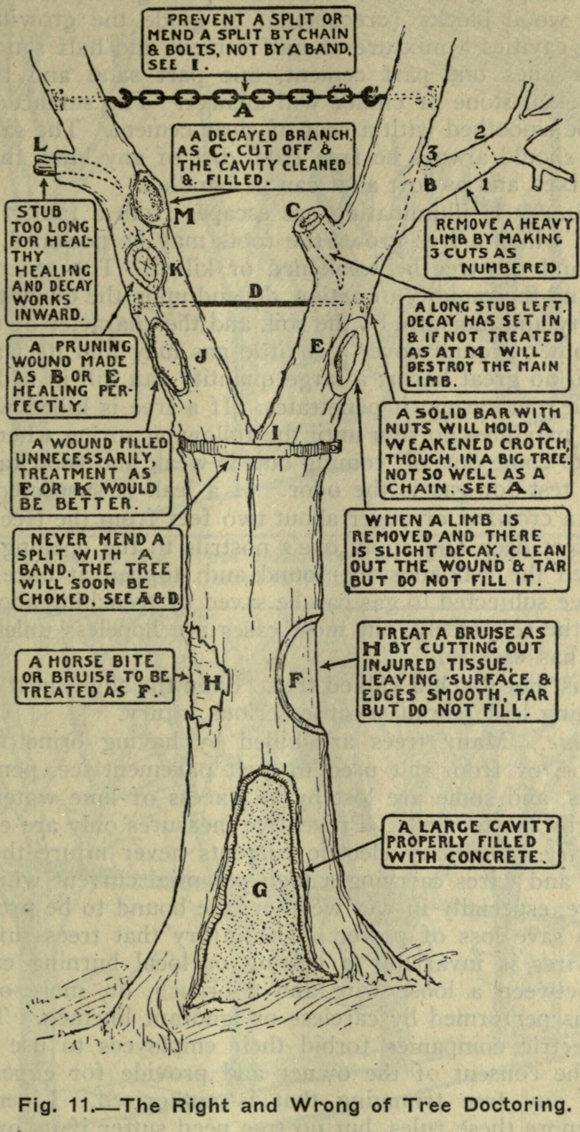

Fig. 11.—The Right and Wrong of Tree Doctoring.

If the cavity cannot be drained, if it is unsightly, or if the tree needs support, a concrete filling may be placed. Before doing this any but a pocket cavity should be shaped so that moisture will drain from it, and set with nails or wires to hold the concrete in place.

In many cases it is advisable simply to clean the cavity, and, without attempting to fill it, cover the opening with cement, sheet-metal, or wood blocks (creosoted), to guide the growing callus. For small cavities a mixture of half cement and half sand is best; for larger ones one part cement, one part sand and two parts gravel, broken stone or cinder will answer. The surface of a filling may be smoothed with a coat of clear cement. The sand, stone or cinder should always be free from dirt of any kind, the cement thoroly mixed and as soft as it can be handled.

Gas poison. If illuminating gas escapes from a faulty pipe into the soil in which a tree grows the roots may be poisoned, cease to function and the tree be weakened or killed. The extent of the damage, and the rapidity of action, depend upon the quantity of gas, the porosity and moisture of the soil, and the character of the pavement or other ground cover. A little gas may find its way to the air and do no great harm; a large quantity can kill in a day every tree whose root system it penetrates. If a tree is killed while it is leafless, it may give no sign until the following spring when its foliage fails to come out, or, coming out, is weak and soon falls. The only sure test for gas is the odor. If a leak is suspected make a hole with a crowbar or auger about two feet from the tree and two or three feet deep and apply one's nostrils to the opening. If gas is indicated the leak must be found and stopped at once. Sometimes a tree subjected to gas can be saved by trenching about it and watering the soil freely, but most cases are hopeless unless only a little gas has escaped.

Fire must not touch a valued tree. Even the slight heat given off by a burning leaf pile may cause serious injury.

Salt, lime. Many trees are killed by having brine from ice-cream tubs, or from salt used to melt pavement ice, penetrate to their roots, and some are lost by an excess of lime water washed from nearby mortar beds. Preventive measures only are effective.

Electricity. Ordinary electric currents never injure the vitality of a tree, and wires carrying a high potential current which might do damage, especially in wet weather, are bound to be properly insulated to save loss of power. The injury that trees suffer from electric wires is invariably a cutting or local burning caused by friction between a loose wire and a branch, or, more often, the mutilations performed by careless or ignorant linemen. The rules of the electric companies forbid their employees to use any tree without the consent of the owner and provide for expert supervision of any tree trimming that is authorized. Linemen frequently ignore these rules, but no tree need suffer if its owner will take the trouble to report the case to headquarters *before* the damage is done. In many cases the company will completely trim and fix up a tree for the privilege of carrying their wires thru it. In this State an owner should always be represented by a Shade Tree Commission.

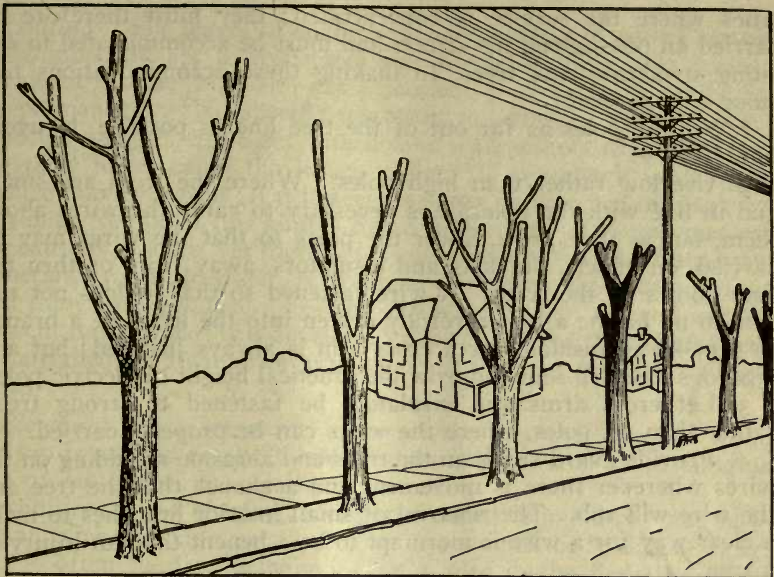

Fig. 12. A Row of Old Trees Butchered to Make Room for High Wires. Compare With Fig. 13.

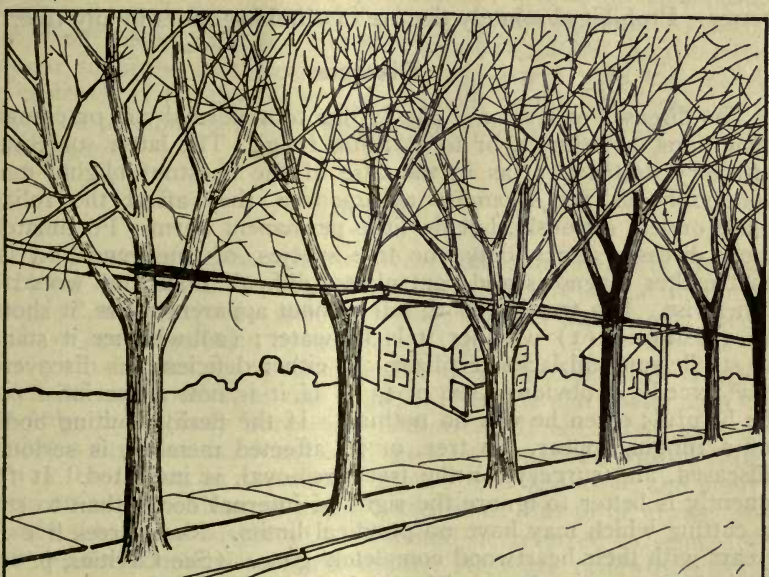

Fig. 13. The Same Trees as in Fig. 12, With Crowns Saved and Wires Carried Thru Them in Cables on Low Poles.

The construction of electric lines is a necessity of our civilization; the cost of carrying the wires underground is prohibitive except in cities where the service is concentrated; they must therefore be carried on poles along the streets and must be accommodated to existing structures and trees. In making these accommodations five rules will govern:

1. Set the poles as far out of the tree line as possible, to avoid interference.

2. Use low rather than high poles. Where the trees are small, and in line with the poles, it is necessary to carry the wires above them, but as they grow, lower the poles so that the wires may be carried, on offsets, brackets and insulators, away from or thru the firm bodies of the trees. A wire fastened so that it does not rub can do no harm; a bolt carefully driven into the heart of a branch to support an insulator or a cross arm is always justified; but any vigorous tree will soon outgrow the practical height of electric poles.

3. Let cross arms and insulators be fastened to strong trees, rather than set poles, where the wires can be properly carried.

4. Provide guard strips on the trees and abrasion moulding on the wires wherever there is movement and a chance that the tree and the wire will rub. The removal of small interior branches to make a clear way for a wire is more apt to be a benefit than an injury to a tree.

5. Have all cuts larger than 1 inch diameter made smooth and carefully treated (see p. 14), to prevent the entrance of disease germs. Prohibit absolutely the use of climbing spurs in any tree.

Diseases

The diseases of trees are chiefly due to abnormal soil or climatic conditions, to injuries, or to parasitic fungi. The latter sometimes are very destructive, as in the case of the chestnut blight; more commonly, as the sycamore anthracnose, they affect the foliage more or less seriously, but do little permanent harm. Fortunately, most diseases attack only one tree species, or one genus,—a law that makes diagnosis and control less difficult than they would be otherwise. If a tree begins to fail without apparent cause, it should be questioned (1) whether it lacks water; (2) whether it stands in sterile soil and lacks fertilizer. If either deficiency is discovered the remedy is obvious (see p. 13). If it is not, a specialist *may* be helpful; often he can do nothing. If the fleshy fruiting bodies of a fungus appear, the tree, or its affected member, is seriously diseased, and surgery, or the tree's removal, is indicated. It frequently is better to ignore the signs of internal decay than to start a cutting which may have no practical limits. Many trees live for years with their heartwood completely gone. (See Cavities, p. 16). It is important to distinguish the fungus fruits which appear only on *dead* wood, from those which are parasitic. A special publication, "Common Diseases of Shade Trees," can be obtained upon request of the State Agricultural Experiment Station, New Brunswick.

Wilting. The leaves of shade trees frequently wilt out of season. Sycamores are apt to lose their first leaves in the spring from a prevalent disease, but soon get a second set and usually suffer little permanently. No specific treatment is advised. Other species, especially maples, are beset with lice or scale insects which by sucking their juices cause the leaves to die. If the attack is slight let nature take care of it; if it is serious spray as directed on page 22. But most trouble of this kind is found in Norway and sugar maples; the cause is obscure, yet there is reason to believe that too little food, sometimes too little water, is available to nourish the heavy leafage that these trees produce. Feeding and watering (p. 13) will usually prevent this trouble; if it develops, let the foliage of the affected tree be curtailed by an interior pruning (p. 14), then fertilize. (Figs. 8, 9.)

Bleeding. This frequently occurs when branches are cut while the sap is moving freely. Under such conditions stop all pruning as loss of sap lowers the vitality of a tree.

Another sort of bleeding, sometimes called "slime-flux," and having an offensive odor, usually begins in a wound, or behind a filling, and is often hard to manage. Like a sore in the flesh the worst possible course is to stop it from the outside; it must be cleansed, sterilized and made to heal from the inside. Let all affected tissue —bark and wood, be cut out with a sharp chisel, the wound pointed at top and bottom (fig. 10) and all edges left smooth: sterilize the exposed surfaces with weak formalin and cover with tar; never use cement. If the trouble is due to a split crotch, clean the crack as well as possible, bolt the parts together, as at D, figure 11, and treat as above.

Insects

Not all insects are harmful to trees: some, tho harmful, are so controlled by natural enemies that they rarely are found in numbers great enough to do serious damage; others attack only trees that have been weakened by neglect or injury.

As with diseases, harmful insects usually confine their attacks to trees of one species, or one genus. Thus the elm beetle attacks elms only, the hickory borer only hickories. It is entirely safe to say that a few insects of any kind on a vigorous tree will do little harm; a few insects on a weak tree should be looked after, and many insects on any tree demand prompt attention. But to be always on the safe side every suspected case should be referred to some authority—an entomologist or a forester. Ants are rarely harmful; their presence about a tree usually means that honey dew, decayed wood or fungus growths are available for their food.

Injurious insects are grouped in three classes: *biters, suckers,* and *borers.*

Biters. These commonly attack the foliage and may work as adults (beetles) or as larvæ (caterpillars or worms). Control is determined by a knowledge of the life history of each species, but a general remedy is to poison their food. The best means is to spray *thoroly* with arsenate of lead according to directions given on the commercial packages. Banding a tree trunk with cotton or some sticky stuff is useful only when the insects are *crawling up.* Bag worms, tent caterpillars, etc., which form conspicuous shelters or colonies in tree crowns, and forms like tussock moths which set egg masses on nearby structures, as well as on the trees, can often be destroyed by hand or by fire even more successfully than by spraying.

Suckers. These appear as minute, crawling insects, frequently protected by woolly, waxy or scaly coverings. They locate on the younger branches, or on the leaves, often in enormous numbers, and live by sucking the sap. Some forms can be washed away with a strong jet of water from a hose, but in most severe cases thoro and repeated spraying with a caustic, or with a penetrating oil, is necessary. Fish-oil soap suds is good for the tenderer forms, especially when reinforced with tobacco extract; lime-sulfur or soluble oil is best for those with scaly armor.

Borers. Boring insects work, as beetles or worms, in the twigs or buds, in heartwood, or, most frequently, in the cambium layer between sapwood and bark. Their presence is indicated by broken branches and by small holes in the bark beneath which wood dust is often found. In our territory a few species attack healthy trees, but most seek out those whose vitality has been lowered. Control is difficult because the pest is mostly out of sight, and, tho help can sometimes be given, it usually is necessary to depend chiefly upon keeping the trees in good health. Against the locust borer anything else is useless. Any hickory tree that is seriously infested with the hickory borer is doomed and should be cut down and burned without delay for the sake of nearby trees, and the latter should be stimulated by feeding to ward off attack. Leopard-moth larvæ are especially fond of young, newly-planted street trees which are struggling to establish themselves. A measure of control is possible by cutting out the boring worms, by crushing them with a wire run into the burrows, by injecting carbon bisulfid, and especially by encouraging insect eating birds. More specific advice is given in a publication of the State Agricultural Experiment Station, New Brunswick, "Insect Enemies of Ornamental Trees and Shrubs," by Harry B. Weiss, which will be sent upon request.

Steam Sterilization of Seed Beds for Tobacco and Other Crops

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FARMERS' BULLETIN 996

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Plant Industry

WM. A. TAYLOR, Chief

Washington, D.C. July, 1918

THE TOBACCO SEEDLING is subject to injury in the seed bed by weeds and a number of parasitic enemies, among which is a fungous root-rot. It is of the utmost importance to secure beds free from weeds and to avoid the use of diseased or weak seedlings. Methods of sterilization have been developed to control seed-bed conditions. The old method of open fires, long practiced in the South, is being replaced by a steaming process the essential feature of which is an inverted pan used to force the steam into the soil. This method of steaming has been widely adopted in certain tobacco-growing districts and is applicable to most, if not all, of them. The process of steaming described is the most practical and economical method of seed-bed control yet developed, and besides eliminating diseases and improving general soil conditions, it kills weed seeds more effectively than the old methods. The cost of sterilizing is more than paid for by the saving in the cost of weeding.

This bulletin describes the necessary equipment and method of operation, with certain special features of seasonal convenience and seed-bed preparation. The method is applicable for working on either small or large seed-bed areas and can be used in all tobacco-growing districts.

With necessary modifications in the apparatus which will readily suggest themselves to the truck grower, the method can be used very successfully to control soil conditions in the greenhouse, in coldframes, or in the field.

STEAM STERILIZATION OF SEED BEDS FOR TOBACCO AND OTHER CROPS.

CONTENTS.

IMPORTANCE OF VIGOROUS TOBACCO SEEDLINGS.

IN TOBACCO PRODUCTION, to grow the right sort of seedling plants is of special importance. Successful transplanting from the seed bed to the field requires vigorous seedlings, and the growth of the crop in the field, especially in the early stages, is largely dependent upon the character of seedling used. Great importance is to be attached to securing strong, healthy seedlings. The young plants in the bed are liable to be injured, and therefore it is necessary to protect them from parasitic and other enemies, which may injure and retard their growth or even kill them. Chief among these enemies are weeds and certain fungous diseases, especially root-rot. Spots in the beds are also frequently found where the soil conditions are such that normal development can not be attained.

These difficulties can be eliminated or greatly reduced by the sterilization of the seed beds, which now is recognized as an important feature in tobacco growing. Seed beds are sterilized for the control of diseases and to kill weed seeds and hibernating insects. When properly done, the saving in weeding costs usually pays for the whole operation of sterilization. The process has the additional advantage of insuring freedom from diseases and the production of more vigorous seedlings.

Sterilization by surface burning has been widely practiced for generations in the South, and in fact has been used at one time or another in nearly all tobacco districts. In the southern districts it has been customary to select each year a new location for the seed

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bed, and the chief object of burning has been to free the bed from weed seeds.

In the northern districts permanent seed beds with glass covers are in more or less general use, and the widespread appearance of fungous diseases, especially root-rot, has made some sort of sterilization necessary. Since open fires are impracticable in these districts a process of steam sterilization has been worked out, which now is used extensively in the cigar-leaf producing districts of the Connecticut Valley, Pennsylvania, and Wisconsin and has been employed with success in several other sections, notably in western Kentucky and Tennessee and in the Burley district. This method is both economical and effective, and with more or less modification is adapted to practically all tobacco-growing districts.

ROOT-ROT IN THE SEED BED.

Within recent years the discovery of the prevalence of a root-rot in the seed bed and in the field has brought about a wide demand for a suitable method of control. The fungus[1] which causes this root-rot is so small that it can be seen only with the aid of the microscope. It may attack the plant at any time after the germination of the seed, and usually can be recognized easily by its effect upon the roots. In the earlier stages brown or black spots appear on the roots. These vary in size from small dots to areas that may extend along the taproot and laterals for an inch or more. In these diseased portions spores, or reproductive bodies of the fungus, may be found by examination with the microscope. As the fungus attacks the roots the diseased parts become successively brown and black, and the root tissues die and fall away, seriously affecting the vitality of the plant.

The fungus lives in the soil from year to year; hence, a bed once infested should not be used again until the disease has been eliminated. New seed beds may be infected by stable manure or decayed leaves used for fertilizing, or by wind-blown vegetable matter carrying spores of the fungus. Seedlings seriously attacked by root-rot are not fit for transplanting, and, furthermore, they may be the means of establishing the disease in the field. It is especially important, therefore, that the disease be eliminated from the seed bed. An effective and economical method of control of the root-rot in the seed bed is found in the sterilization of the seed-bed soil.

OLD METHOD OF STERILIZING TOBACCO SEED BEDS.

For many years before the adoption of sterilization with steam, open fires on the soil had been used. The open-fire method came into use chiefly because of its value in freeing from weed seeds the spot

[1] The technical name of this fungus is *Thielavia basicola*.

selected for the seed bed. It has been practiced for a great many years in the tobacco-growing areas south of Maryland and Ohio, where it is common to locate the seed bed at the edge of or in the woods. The area selected for use as a seed bed is cleared, the ground broken, and brush and wood laid over it and burned. The degree of thoroughness with which the surface burning is done in different sections depends on the character and quantity of the fuel supply and on other local conditions. When the burning is done thoroughly the resulting heat is sufficient to free the soil of all fungi and weed seeds to a depth of several inches, but the organic matter of the soil is largely destroyed, and later the surface of the bed is likely to bake during even short dry periods, killing a large percentage of the seedlings.

Barn manure and fertilizers containing organic matter must be applied after firing to prevent their decomposition in the burning, and this opens the way for adding to the seed bed material carrying fungous spores or weed seeds. If excessive quantities of ashes are left on the bed the growth of the seedlings may be affected, and sometimes the germinating seed may be killed.

In order fully to accomplish the purpose of burning, it is necessary to secure a high heat over the surface of the entire seed bed. This requires large quantities of wood, and the ever-increasing scarcity of wood in certain localities has made it practically impossible longer to pursue this method.

A modification of the open-fire method is found in the portable wood-burning furnace. This furnace consists of a heavy fire box, 9 feet long, 3 feet wide, and 18 inches deep, constructed of iron and set close to the ground. On top of this is set a pan 9 by 3 feet and 10 to 12 inches deep. The whole apparatus rests at one end on a pair of wheels and at the other end on two legs. It is furnished with two handles for lifting and drawing. A fire is made in the fire box and the soil from the seed bed, to a depth of 4 or 5 inches, is shoveled into the pan and covered. The heat from the fire below brings about thorough serilization. While more effective than the open fire on the bed, the furnace has the disadvantage of being slow in operation and equally expensive in fuel consumption. It also necessitates a second handling of the soil.

THE STEAM-PAN METHOD OF STERILIZATION.

The steaming of the soil is the most satisfactory method of sterilization which has been developed up to the present time. The direct application of the steam to the soil by means of an inverted pan or hood has now been in successful operation for a number of years.[1] Thus far

[1] This method has been briefly discussed in Farmers' Bulletin 343, "The Cultivation of Tobacco in Kentucky and Tennessee" (1909), and in Bureau of Plant Industry Bulletin 158, "The Root-Rot of Tobacco Caused by Thielavia Basicola" (1909).

this process has been most extensively employed perhaps in the Connecticut Valley, but because of its many advantages and its effectiveness it is being widely adopted in other tobacco-growing districts.

PREPARATION OF THE SEED BED FOR STEAMING.

The seed bed is thoroughly prepared in the usual manner for sowing the seed. The soil is well worked, the fertilizers spread and mixed in the soil, and the bed brought to fine tilth, so that after the steaming is completed it is only necessary to rake the bed lightly before sowing the seed. It is important that nothing but the seed and the diluting material, also sterilized if necessary, should be added to the bed after sterilization.

A comparatively dry bed is the first requisite for successful steaming, as it is practically impossible for the steam to penetrate wet soil. Glass-covered beds may be dried with comparative ease by covering them with sash several weeks before steaming. The bed is protected from the rains and snows of spring, and the sun's rays warm the soil and drive off excessive moisture. Cloth-covered beds may be protected for two weeks before steaming when rain or snow threatens by stretching over them cloths which have been painted with a thin mixture of linseed oil and drier.

EFFECT OF FROST IN THE SOIL.

The presence of frost in the surface soil retards the penetration of the steam and makes it necessary to continue the process for an unusually long period. The ground must first be thawed before the desired heating can be brought about, and this causes a fuel consumption more than double that required where the soil is in proper condition. Where there is frost in the surface soil the steam does not penetrate more than a few inches, because of the condensation of the steam in the cold ground.

In order to thaw out the seed beds before steaming, a good practice is to cover them with glass for several weeks, as has been suggested for wet beds. The glass allows the heat from the sun's rays to be confined within the bed during the day, warming the soil and putting it in a mellow condition. Without such preparation even partial sterilization would be impossible in some sections till late in the spring.

FALL STEAMING OF THE SEED BED.

Steaming has been done in the fall by many growers because of the disadvantages experienced in the spring due to rains and snows or the frozen condition of the ground. Usually the seed-bed soil can be put in excellent condition in the fall when the land is dry and before the air temperature is low enough to freeze the ground. An added advantage is found in the seasonal distribution of labor, making it desirable to do the work at this time, when there is no particular rush to complete the steaming.

Fall steaming has the disadvantage that infected material and weed seeds may be blown into the beds during the winter, but where windbreaks of high, tight board fences are placed around the beds this disadvantage is reduced to the minimum. There also is the added disadvantage in certain cases, particularly where the seed beds are located on low ground, of the ground becoming flooded during winter or spring thaws. The surface water may carry spores from adjoining infected land to the sterilized seed bed. It is necessary at all times to have thorough drainage in and around the seed beds.

Especially in regions of clay soils where glass frames have not come into general use fall steaming finds particular favor because of the practical impossibility of drying the seed-bed soil early enough in a wet spring.

Where the work is done in the fall all preparations are made as for spring steaming. If manure is used, the quantity added in the fall should be a little more than that ordinarily used in the spring, because of the possible loss by leaching. Commercial fertilizers can be applied safely in the spring.

EQUIPMENT NEEDED FOR STEAMING SEED BEDS.

The equipment recommended for steam sterilizing seed beds under average conditions consists of the following:

A portable boiler of 20-horsepower or larger capacity.
Heavy ¾-inch steam hose, 25 feet.
Iron ¾-inch pipe sufficient in length to carry the steam from the boiler to all parts of the beds.
Heavy canvas or burlap, 216 square feet.
A steaming pan to cover an area of about 72 square feet.
Attachments for the steaming pan, consisting of 4 ring bolts 6 inches long, with 3-inch rings; 4 bars or ax handles; felt packing 2 inches wide, sufficient in length to extend around the pan; the same length of 4-inch hoop iron or of 2-inch angle iron; one ¾-inch nipple 6 or 7 inches long, threaded on both ends; two ¾-inch leather gaskets; two ¾-inch nuts or threaded washers.

The boiler is the item of greatest expense, the rest of the equipment being comparatively inexpensive. With proper care the entire apparatus should last for a number of years.

A boiler of sufficient capacity is the essential factor in successful sterilization, because large volumes of high-pressure steam are required. Experience has shown that a boiler of at least 20-horsepower is necessary for efficient steam production when using a steaming pan of the size mentioned above. In some localities, where seed beds have been sterilized with steam for a number of years, farmers are supplied with their own boilers; in other places one boiler is used cooperatively by several planters. Road rollers, steam tractors, and packing-house boilers are frequently called into use for seed-bed work. In some sections the owners of steam tractors or portable boilers go from place to place, sterilizing beds at fixed prices. Such operators are usually supplied with all necessary equipment, though sometimes they provide only the boiler and a fireman.

CONSTRUCTION OF THE STEAMING PAN.

In the permanent seed bed the pan is of such width as to fit snugly within the sides of the frame, and its length varies according to requirements. A pan having an area of 72 square feet is sufficient for a 20 or 25 horsepower boiler, and a larger pan is difficult to move. On a bed 6 feet wide the pan should be 12 feet long. Where only a

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FIG. 1.—Inverted wooden pan for the steam sterilization of seed beds, showing the connection of the steam hose. Note the fine preparation of the seed-bed soil. A light raking only will be necessary before sowing the seed, as all fertilizers are applied before steaming.

small boiler is available, the area of the pan should be correspondingly reduced, so that the boiler can maintain the desired pressure of at least 80 pounds.

Sterilizing pans made of galvanized iron have been extensively employed, but as wooden pans are cheaper and are easily made at home, wood is the material now coming into general use. The wooden pan further possesses the distinct advantage of reducing the loss of heat by radiation.

The pan is simply a shallow box, 4 inches being the preferred depth. If it is deeper, much of the desired effect is lost through the more rapid cooling of the steam in the larger space exposed above the soil. The frame is made of 2 by 4 inch material; across this are laid matched boards (⅞ by 4 inches). It is advisable to put white lead in the grooves to prevent the escape of steam. The boards must be securely nailed in the tongue and at the sides to prevent drawing, as they swell by absorption of moisture during the process of steaming. These cover boards are further secured by two boards or planks which are laid over them on the outside, at right angles to them, extending the length of the box, and which are very securely nailed at the ends (fig. 1). The cover boards are then nailed from the inside to the outside planks, the object being to prevent the swelling and warping of the cover boards. A good view of the inside construction of the box is shown in figure 2.

Two ring bolts are set in each side of the frame on the top, one near each corner. Through the rings ax handles or bars are thrust to serve as handles in moving the pan along the bed, as shown in the title-page illustration.

A strip of $\frac{1}{4}$-inch felt packing, 2 inches wide, is placed along the lower edge of the frame, on the outside, to prevent the escape of the steam. The hoop iron is then laid on the packing and

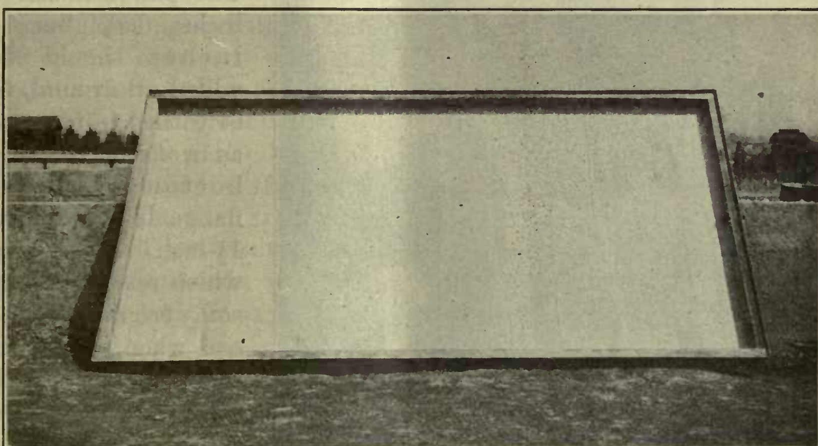

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FIG. 2.—The under side of a wooden sterilizing pan made of 2 by 4 inch frame and $\frac{7}{8}$-inch matched cover boards. Hoop iron laid over thin felt and lapped over the edge surrounds the outside of the frame, forming a knife-edge joint in the soil to prevent the loss of steam. A $\frac{3}{4}$-inch nipple is inserted in one end, through which the steam enters.

nailed every 4 inches, one-half its width extending beyond the lower edge of the frame, as shown in figures 2 and 3. When the packing can not be had, the iron is nailed to the inside of the frame instead of the outside. Instead of the hoop iron, 2-inch angle iron is sometimes used. This is fastened to the lower side of the frame, to form a tight joint when the box is laid on the soil. A piece of thin packing serves to prevent the escape of steam between the iron and the bottom of the wooden frame to which it is nailed. Angle iron, because of its heavier character, will not bend and is better than hoop iron, but it requires careful working to fit it to the frame.

In the middle of one end of the frame is set a $\frac{3}{4}$-inch pipe-threaded nipple, 6 or 7 inches in length, through which the steam is delivered into the pan. The nipple should project 3 inches from the box, to afford a convenient attachment for the hose, and it should be held securely in place on the 2 by 4 inch end frame by lock nuts, closing on leather gaskets, as shown in figure 3.

The pan is placed on the bed, open side down, the hoop iron or angle bar cutting into the ground to form a knife joint, and the steam leaving the boiler under pressure enters the pan and quickly penetrates the soil.

The iron sterilizing pan which is sometimes used is similar to the wooden pan in shape and size. It has the advantage of lighter weight, making it easier to move. It is made of 16 or 18 gauge galvanized iron, supported by ribs of $1\frac{1}{2}$-inch angle bars. The pan is made 4 inches deep, but $1\frac{1}{2}$ inches should be added all around, to be turned in to serve as a flange on the bottom. To this flange is attached a $1\frac{1}{2}$-inch angle iron, which rests upon the soil, forming the seal when the pan is placed upon the bed. The angle iron also serves as a rib for the lower part of the pan. Other ribs of angle iron are run across the top, two in the middle and one on each edge, holding the pan rigid. A $\frac{3}{4}$-inch nipple is firmly secured by flanges and solder in the middle of one end for the hose connection. Ring bolts for lifting are attached by flanges on the sides near the ends of the pan, which is rendered steam tight by close riveting and solder.

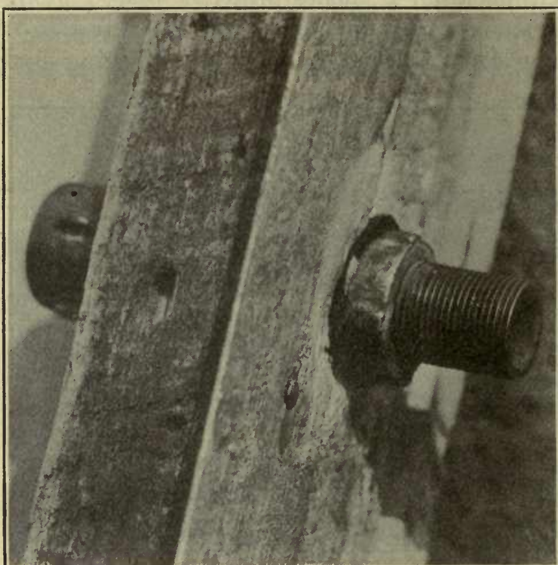

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FIG. 3.—Nipple inserted in the middle of one end of the frame of the sterilization pan. Note the leather gasket secured under the lock nut to prevent the escape of steam. Another gasket is similarly held by the nipple on the inside.

CARRYING OUT THE STEAMING PROCESS.

The boiler is placed close to the bed and where practicable at an equal distance from each end. Steam traction engines and portable boilers have a marked advantage, because they can be easily moved as the work progresses, allowing the use of a short pipe, giving a minimum loss of heat by radiation. The pan is set on one end of a bed with its inlet nearest the boiler. The hose is attached to the pan and to the pipe leading from the boiler. Soil is banked around the edges of the pan to prevent the escape of the steam. The title-page illustration shows the boiler and apparatus connected for operation.

It is desirable to maintain a pressure in the boiler of 100 pounds, and if the pressure drops below 70 pounds the steam should be shut off, as this is the minimum for successful sterilization. Steam of high pressure has much greater penetrating power than steam of low pressure, and it is important to realize that the efficiency of the operation is greatly increased by dry high-pressure steam. A little experience in firing the boiler and operating the pan is necessary before one can maintain high pressure while supplying steam to the pan. Experienced operators can hold 100 to 125 pounds pressure for continuous operation 24 hours per day. The outlet valve should be opened only part way, so that the pressure of the boiler can be kept uniform and unnecessary blowing of the soil in front of the inlet prevented. A great volume of steam is not so essential as great penetrating power.

After 30 minutes the steam is shut off and the pan moved along the bed to the next area. One end of the pan should slightly overlap the area just steamed, thus leaving no strip unsterilized. Four attendants, one man at each corner, are usually required to lift the pan, using bars or ax handles inserted through the ring bolts. Immediately after moving the pan, the steamed area is covered with a canvas or burlap blanket. This is important, because the heat must be conserved in the surface soil to allow it to reach the lower soil by conduction. It is desirable that covers be supplied for the entire bed, so that each area will be covered for several hours after steaming.

Experienced operators have found it advantageous to use two pans alternately, eliminating the necessity of moving the pan immediately after the steam is shut off. The moving of the pan immediately after operation is quite disagreeable to the workers because of the volume of steam held under the pan. There is also a considerable loss of heat when the pan is moved before the heat has reached the lower soil layers.

TEMPERATURES SECURED.

In sandy soils, after 30 minutes' steaming, the temperatures to be expected in the upper 2 inches of soil directly under the pan are approximately 208° to 212° F., at 3 to 4 inches 170° to 180°, and at 6 inches 120°. Two hours after the removal of the pan the temperature at 6 inches should be about 160° F. If a thermometer is not available, the efficiency of the steaming operation can be easily determined by burying a potato 4 inches under the surface of the soil. The potato should be well cooked when the pan is removed, and this is a common method of determining the work done by a steaming outfit. Although the temperatures reached directly under the pan are quite high, little heating effect is to be noted away from the edges of the pan.

Clay soils, because of their heavier texture, require longer periods for steaming than sandy soils. Steam penetration and heat conduction are not as rapid as in the more open sandy loams, and it is especially important that these soils be as dry as possible at the time of steaming. The moistening of the soil by rainfall or snow just before steaming prevents the rapid heating of the soil and the full penetration of the steam, and the efficiency of the work is greatly reduced.

COST OF STEAMING.

Contractors who furnish the boiler and a fireman may charge according to the area steamed at an average rate per 100 square feet, or they may charge a flat daily rate. The charges for this work vary in the several tobacco-growing sections, ranging from 50 cents to $1 per 100 square feet, or from $6 to $12 a day, and the contractor may or may not furnish the pan and fuel.

The fuel consumption is usually reckoned at one-half ton of soft coal for every 1,000 square feet of seed bed.

Where the grower owns the boiler, the costs of operation are somewhat lower. The average area covered in a 10-hour day is 1,000 square feet and the cost is approximately $6. It is also better to use two pans, so that there may be no delay in steaming due to the shifting of the pan. One attendant is required constantly to fire the boiler; three others must be ready at intervals during the day to help him move the pans.

The labor cost can be reduced considerably by using a rack for lifting the pan. For this rack two pairs of buggy or light wagon wheels set on axles a little longer than the width of the pan are joined together by a light frame. This frame should be 4 feet shorter than the pan. A long rod or lever is attached in the middle of each end of the frame, to allow for the easy lifting of the pan. The lever is provided with a hook at the end of its resistance or lifting arm. To the ring bolts at each end, a substantial rope is fastened with sufficient play for the hook of the lever to hold the rope conveniently. By hooking the rope and using the frame of the carriage as a fulcrum, the pan is lifted. The lever arms can be hooked in position by a wire or clutch after the pan is lifted. The sides of the seed-bed frame form a guide for the wheels, thereby making it a simple operation for one man to handle and move a pan.

On account of the possible occurrence of rains and snows during the period for sterilizing, it is advantageous even on small farms to operate 24 hours per day in favorable weather. Large growers do this because of the convenience and economies in fuel and labor.

The permanent seed beds are usually equipped with a water-supply system; where this is not the case the transportation of water for the boiler is an additional item of expense.

In considering costs, one should bear in mind the fact that a thoroughly steamed seed bed is practically free from weed seeds, thereby eliminating the cost of weeding. The amount saved in weeding will probably more than cover the cost of sterilization, as two good weedings usually cost more than $6 per 1,000 square feet. Figure 4 illustrates the effectiveness of the steaming-pan method in killing weed seeds. On the right of the partition it will be seen that the sterilized area is practically free from weeds, whereas the unsterilized portion on the left was worthless because the weeds had forced out nearly all of the tobacco plants. Additional advantages are that the plants are more vigorous and are ready for transplanting 10 to 14 days earlier than plants in unsterilized beds. As has been stated, where root-rot or other fungous diseases are present, some form of

FIG. 4.—A tobacco seed bed, showing a partition between the steamed and the unsteamed portions. Both sections were sown at the same time with similar seed, but the weeds in the unsteamed section (at the left) practically killed the tobacco seedlings. No weeds grew on the steamed part.

sterilization is essential for the production of healthy seedlings, and steaming is decidedly the most effective process yet developed for insuring the elimination of these diseases.

IMPORTANT CONSIDERATIONS.

Sterilization so improves the soil conditions that less fertilizer is necessary than on unsterilized ground. One should exercise caution against reinfecting the soil by walking on the steamed bed, using infected rakes, water from stagnant ponds, a solution of manures, or seed sown with unsterilized vegetable matter, such as decayed wood, punk, or decomposed leaf tissue. Finely sifted raw bone meal, thoroughly sterilized punk, and land plaster are excellent materials for spreading the seed. They should be very slightly moist to spread well between the fingers and to retain the seed in the mixture. Root-rot is found in some seed beds that have been thoroughly steam sterilized. Such infection may have been carried by fertilizers applied after the steaming, by decayed vegetable matter used to spread the seed in sowing, or by contamination with adjoining diseased soil if the bed has not been kept covered after having been sterilized. Diluting material, like punk, can be readily sterilized at the time of steaming the soil by placing it in a bucket inserted under the pan, or it may be kept in the oven of a kitchen stove for several hours at a moderate temperature.

The seed may be safely sown 12 hours after the steaming of the beds. Dry seeds only should be used. There is a temporary injurious action in the soil after steaming which retards the growth of the young plant for 10 to 14 days and sometimes longer. Sprouted seed is more readily injured by this temporary effect of steaming, but when dry seed is sown the effect has largely disappeared when the first shoots appear. This condition may sometimes retard the development of the plants appreciably during the first three weeks after sowing, but this is followed by a decided stimulating action, so that plants in sterilized beds are usually ready for setting two weeks earlier than plants on unsteamed beds.

Steamed seed beds require much more water to produce a crop of seedlings than untreated seed beds. The surface soil is inclined to dry or crumble, and because of this tendency it is advisable to locate the seed beds near an easily available water supply. During clear, bright weather the beds should be inspected late in the morning and again in the middle of the afternoon, as the soil is very likely to dry out, killing young seedlings. Because steamed soil requires larger quantities of water the tendency is to overwater. In this, care must be used, especially if the beds are sown rather thickly, since there is danger of the occurrence of damping-off under certain conditions. It is an advantage to keep the seed beds occupied after the tobacco plants are taken off. Steamed beds are especially adapted for growing late vegetable crops, which practice tends to keep the beds free from weeds.

THE FORMALDEHYDE METHOD OF STERILIZING SEED BEDS.

When steam sterilization can not be used, formaldehyde may be employed to control seed-bed diseases. One gallon of commercial 40-per-cent formaldehyde solution is diluted in 50 gallons of water. This solution is applied at the rate of 2 quarts per square foot of seed bed, using a common sprinkling can.

The seed bed should be prepared for sowing, and to do the most effective work the soil should be dry enough to absorb all of the formaldehyde solution. To prevent the washing of the soil, the necessary quantity should be put on in a number of applications at intervals of, say, 20 to 30 minutes. When all the solution is absorbed the bed should be covered with blankets for 24 hours to confine the fumes. It should then be aired for 8 or 10 days to allow the escape of the fumes from the soil. The seed should not be sown so long as there is a trace of the formaldehyde, for this will kill the germinating seed or young seedlings.

The use of formaldehyde is recommended only when steam sterilization is not practicable. Its cost is greater than the cost of steaming, and it is usually less effective.

APPLICATION OF THE STEAMING PROCESS TO CROPS OTHER THAN TOBACCO.[1]

The steaming of greenhouse soils with coils of pipes embedded therein had been practiced for a number of years prior to the development of the inverted-pan method of steaming as applied to tobacco seed beds. Since its adoption on tobacco seed beds the inverted-pan method of steaming has been demonstrated to be effective for greenhouse work, and, further, it is easily seen that the method can be applied to hotbeds and coldframes for various other crops. It is especially valuable in the production of vegetable crops where it is desired to control damping-off and other fungous diseases which may be in the soil. The special requirements for any particular situation will readily suggest themselves, and the apparatus described for tobacco seed beds can be easily modified in size and shape of pan and arrangement of piping to suit almost every condition of soil steaming in greenhouses, outside frames, or even in open fields.

[1] It is upon the suggestion of Dr. W. A. Orton, Pathologist in Charge of Cotton, Truck, and Forage Crop Disease Investigations, that the attention of the truck grower is directed to the application of the inverted-pan method of steaming for the control of certain vegetable diseases.

THE FARMERS OF THIS COUNTRY are as efficient as any other farmers in the world. They do not produce more per acre than the farmers in Europe. It is not necessary that they should do so. It would perhaps be bad economy for them to attempt it. But they do produce by two to three or four times more per man, per unit of labor and capital, than the farmers of any European country. They are more alert and use more labor-saving devices than any other farmers in the world. And their response to the demands of the present emergency has been in every way remarkable. Last spring their planting exceeded by 12,000,000 acres the largest planting of any previous year, and the yields from the crops were record-breaking yields. In the fall of 1917 a wheat acreage of 42,170,000 was planted, which was 1,000,000 larger than for any preceding year, 3,000,000 greater than the next largest, and 7,000,000 greater than the preceding five-year average.

But I ought to say to you that it is not only necessary that these achievements should be repeated, but that they should be exceeded. I know what this advice involves. It involves not only labor, but sacrifice; the painstaking application of every bit of scientific knowledge and every tested practice that is available. It means the utmost economy, even to the point where the pinch comes. It means the kind of concentration and self-sacrifice which is involved in the field of battle itself, where the object always looms greater than the individual. And yet the Government will help, and help in every way that is possible.—From President Wilson's Message to the Farmers' Conference at Urbana, Ill., January 31, 1918.

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5

RODENT PESTS OF THE FARM

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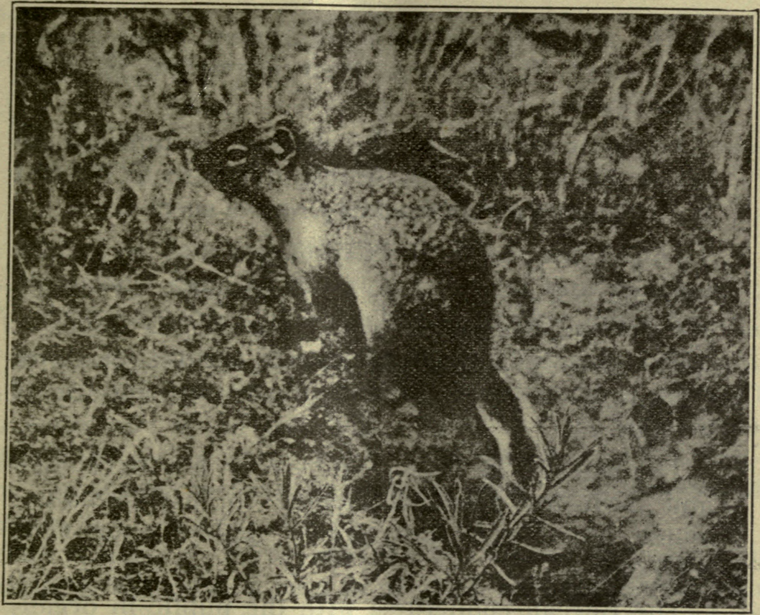

Columbia Ground Squirrel B123M

FARMERS' BULLETIN 932

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Biological Survey

E. W. NELSON, Chief

Washington, D. C. Issued July, 1918

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THE ANNUAL losses from rodent pests in the United States have been estimated as fully $300,000,000.

About two-thirds of the damage is inflicted by house rats and mice (both introduced from the Old World) and the remainder by native species.

This enormous waste of resources may be greatly reduced and largely prevented through systematic and organized campaigns against the noxious species.

The bounty system effects no permanent relief from rodents and is far more costly than the use of poisons.

The Bureau of Biological Survey has developed and perfected practical methods of extermination which have been successfully applied over wide territory.

The Bureau cooperates with the public in organizing and carrying out systematic campaigns against animal pests and invites correspondence on the subject.

Protection of their natural enemies is urged as an important aid in controlling rodent pests.

RODENT PESTS OF THE FARM.

CONTENTS.

INTRODUCTORY.

RODENTS are among the most persistent and aggressive of the animal enemies of the tiller of the soil, and against them he is often more helpless even than against insect pests, because he has had less instruction as to their habits and the means of fighting them. To assist him by giving short accounts of the more important rodents that injure farm, ranch, and orchard, together with brief practical directions for destroying the pests, is the purpose of this bulletin.

The rodents of North and Middle America include about 77 distinct groups called genera, 44 of which have representatives north of Mexico. These 44 groups include about 750 forms that inhabit the United States and Canada. Many of them live in deserts, mountains, and swamps and rarely come in contact with cultivated crops. These, therefore, can not be classed as injurious; and, indeed, many of them are beneficial to the soil, as they stir it up and fit it for future agricultural uses. A few rodents feed largely upon insects and help to keep a check upon the hordes of grasshoppers and similar pests. Certain of the rodents, too, as the beaver and the muskrat, have a decided economic value as fur bearers; while some, as the rabbits and the tree squirrels, afford sport in hunting and are useful as human food.

The noxiousness of rodents depends largely upon the locality in which they live and upon their relation to man and his interests. All are chiefly vegetarian in diet and by reason of their rapid reproduction are capable of becoming pests; but it is only when they are actively injurious that means of control are needed.

Probably no term applied to animals has been so generally misused as the word "vermin." Originally restricted to small creeping animals, wormlike in their movements, and especially to insects, the term has been broadened by English gamekeepers to include all enemies of ground game. Usage now sometimes applies the term to all animals that are supposed to be either harmful or useless. Writers on game protection are often vehement in their condemnation of "vermin," forgetting that what may be so considered by one person may from the standpoint of another be highly useful. The interests of the sportsman or gamekeeper often run counter to those of his farmer neighbor, and they frequently clash on such matters as rabbit protection and the enforcement of trespass laws. A better understanding of the habits of birds and mammals, especially of their food and the interrelation of species that prey and are preyed upon, will greatly restrict the number of animals that may properly be called "vermin." Under natural conditions few can rightly be so designated; but man has interfered with nature until he has disturbed its balance. He has introduced artificial conditions and so changed the environments of animals that some have prospered while others have been driven out. The species that have been most favored by man's activities are, unfortunately, those that have been most harmful to his interests. As a result he must now make warfare upon foes that were once inoffensive.

HARMFUL NATIVE RODENTS.

Only four of the many forms of wild rodents found within the United States have been introduced; the others are indigenous to the country. Among harmful native rodents are included the short-tailed field mice, white-footed mice, cotton rats, kangaroo rats, pocket gophers, ground squirrels, prairie-dogs, woodchucks, and rabbits. A few others occasionally do slight damage to crops or other property.

SHORT-TAILED FIELD MICE.

Several groups, or genera, of short-tailed field mice occur in the United States and Canada, but only two of them have, by reason of their abundance in cultivated regions, become serious pests. These are commonly known as meadow mice[1] and pine mice[2] (fig. 1).

Meadow mice are widely distributed, inhabiting most parts of the Northern Hemisphere. In the United States we have many species, but, fortunately, have thus far had no widespread plagues of the animals like those that have occurred abroad. However, there have been many local outbreaks, notably that of 1907–8 in the Humboldt Valley, Nevada, where much of the alfalfa crop was utterly ruined. Fortunately, few of our species come in contact with farm operations,

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[1] Genus *Microtus*. [2] Genus *Pitymys*.

but these few sometimes multiply enormously and inflict heavy damage by attacking and girdling fruit trees and by destroying other crops. Their presence is indicated by their many surface trails under dead grass, weeds, or other trash. The animals usually avoid open spaces, where they are exposed to such enemies as hawks and owls, birds which make these mice the chief part of their diet.

Depredations by meadow mice may be greatly lessened and serious outbreaks prevented by clean cultivation, the elimination of old fence rows, and the prompt burning of dead weeds and other trash.

Pine mice, like moles, burrow underground, where their tunnels are similar in extent and intricacy to the surface runways of meadow mice; but as their natural habitat is the woods, they come less frequently in contact with farm crops. Their most serious depredations

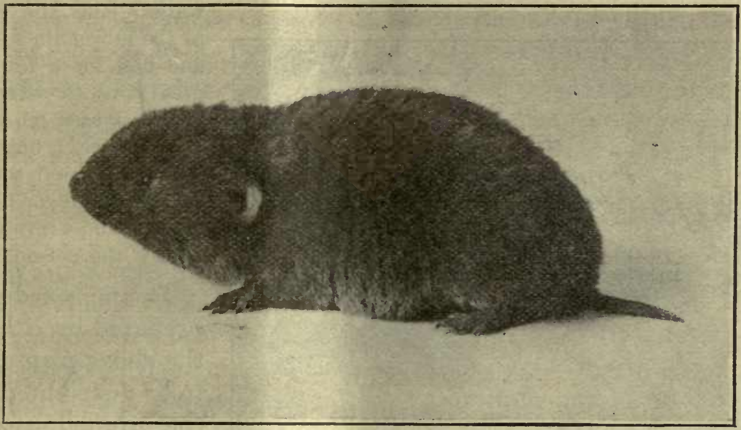

FIG. 1.—Pine mouse. B670M

are in orchards, although they often do great damage in lawns and plantations adjacent to woodlands by eating bulbs and gnawing the roots of shrubbery. In such situations they also frequently destroy potatoes, peanuts, and newly planted seeds of truck crops. Their concealed operations permit them to do much harm before their presence is suspected. For this reason, also, they are less often the victims of birds of prey.

Ordinary mouse traps of the guillotine type, baited with rolled oats and set in runways of either meadow or pine mice, will free a small area of the animals (fig. 2); but for large areas or for operations against considerable numbers of these mice, poisons are more effective.

For poisoning meadow mice on large areas the following methods are recommended:

Dry-grain formula.—Mix thoroughly 1 ounce powdered strychnin (alkaloid), 1 ounce powdered bicarbonate of soda, and $\frac{1}{8}$ ounce (or less) of saccharin.

Put the mixture in a tin pepperbox and sift it gradually over 50 pounds of crushed wheat, or 40 pounds of crushed oats, in a metal tub, mixing the grain constantly so that the poison will be evenly distributed. Dry mixing has the advantage that the grain may be kept any length of time without fermentation. If it is desired to moisten the grain to facilitate thorough mixing, it will be well to use a thin starch paste (as described below, but without strychnin) before applying the poison. The starch soon hardens, and fermentation is not likely to follow.

If crushed oats or wheat can not be obtained, whole oats may be used, but they should be of good quality. As mice hull the oats before eating them, it is desirable to have the poison penetrate the kernels. A very thin starch paste is recommended as a medium for applying poison to the grain. Prepare as follows:

Wet-grain formula.—Dissolve 1 ounce of strychnin (sulphate) in 2 quarts of boiling water. Dissolve 2 tablespoonfuls of laundry starch in ½ pint of cold water. Add the starch to the strychnin solution and boil for a few minutes until the starch is clear. Pour the hot starch over 1 bushel of oats in a metal tub and stir thoroughly. Let the grain stand overnight to absorb the poison.

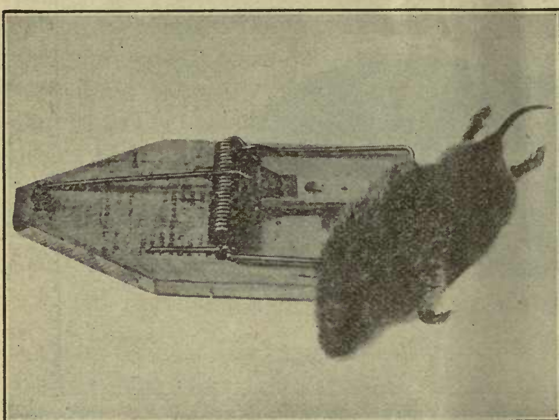

FIG. 2.—Meadow mouse caught in guillotine trap.

The poisoned grain prepared by either of the above formulas is to be distributed over the infested area, not more than a teaspoonful at a place, care being taken to put it in mouse runs and at the entrances to burrows. To avoid destroying birds it should whenever possible be placed under such shelters as piles of weeds, straw, brush, or other litter, or under boards. Small drain tiles 1½ inches in diameter have sometimes been used to advantage to hold poisoned grain, and old tin cans with the edges bent nearly together will serve the same purpose.

Chopped alfalfa hay poisoned with strychnin was successfully used to destroy meadow mice in Nevada during the serious outbreak of the animals in 1907–8:

Alfalfa formula.—One ounce of strychnin (sulphate) dissolved in 2 gallons of hot water was found sufficient to poison 30 pounds of chopped alfalfa previously moistened with water.

This bait, distributed in small quantities at a place, was very effective against the mice and did not endanger birds.

For poisoning mice in small areas, as lawns, gardens, seed beds, vegetable pits, and the like, a convenient bait may be prepared from ordinary rolled oats, as follows:

Oatmeal formula.—Dissolve $\frac{1}{8}$ ounce of strychnin in 1 pint of boiling water and pour it over as much oatmeal (about 2 pounds) as it will wet. Mix until all the grain is moistened. Put it out, a teaspoonful at a place, under shelter of weed and brush piles or wide boards.

The poisoned oatmeal is adapted for killing either meadow or pine mice, but for the latter sweet potatoes, prepared as follows, have proved even more effective:

Potato formula.—Cut sweet potatoes into pieces about the size of grapes. Place 3 quarts of these cut baits in a pan or bucket, and from a tin pepperbox slowly sift over them $\frac{1}{8}$ ounce of powdered strychnin mixed with an equal quantity of baking soda, stirring constantly so that the poison is evenly distributed. Poison should be applied as soon as potatoes are cut and bait should be put out while fresh.

The bait, whether of grain or pieces of potato, may be dropped into the pine mouse tunnels through the natural openings or through holes made with pieces of broom handle or other stick. Bird life will not be endangered by baits thus placed.

WHITE-FOOTED MICE.

White-footed mice, or deer mice,[1] are of many species and are present in almost all parts of the country. They live in fields and woods, and while they feed on grain to some extent, they rarely are present on cultivated lands in sufficient numbers to do serious harm. Occasionally they invade greenhouses or hotbeds and destroy seeds or sprouting plants. In the seed beds of nurserymen, and especially in those of the forester who tries to grow conifers, they often do much injury. They are, in fact, the most serious pests known to the conifer nurseries of the Forest Service.

In ordinary places white-footed mice may be readily poisoned by the methods recommended for meadow and pine mice. Unfortunately the seed of the pine is the favorite food of these animals and where it is planted in abundance they refuse to take grain baits. Crushed pine seeds poisoned with strychnin by the "wet-grain formula," given above, have proved effective in such places. Preliminary poisoning of these mice on areas to be seeded to pine is highly recommended. For seed beds, poisoning on surrounding areas two or three times a year will usually prevent the approach of mice and give immunity to the planted seeds.

COTTON RATS.

In parts of the Southern States a large native mouse, or rat, commonly known as the cotton rat[2] (fig. 3), often becomes a field pest.

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[1] Genus *Peromyscus*. [2] Genus *Sigmodon*.

Of some 28 known forms of this animal, 7 occur north of Mexico, in Texas, New Mexico, Arizona, Oklahoma, and southern Kansas and along the Gulf coast from Louisiana to Florida.

Cotton rats damage growing crops to some extent, but are especially destructive to grain in shocks. In many of their habits they are similar to meadow mice, and they multiply fully as fast. They chiefly inhabit weedy borders and areas covered with old grass, where they are sheltered from enemies. They do not often attack the bark of trees, but, being larger than meadow mice, are capable of destroying much more grain in a short time. They ruin melons and other truck crops and have been a serious pest to date growers in Arizona.

Cotton rats are easily poisoned by the same methods recommended for destroying meadow mice.

FIG. 3.—Cotton rat (dead) and nest, Pecos Valley, Tex.

KANGAROO RATS.

Fifty-nine known species and races of the kangaroo rat (fig. 4), belonging to three groups, inhabit North America, and 45 of them occur north of Mexico. Two groups[1] are widely distributed in the West; they differ in anatomical characters, but are much alike in general appearance and habits. A third group[2] includes three species and one race of very small animals, all of which are rather restricted in range and of slight economic importance. Kangaroo rats are gentle, easily tamed, and make sprightly and interesting pets. They live mostly in deserts, sagebrush country, and sandy places and are harmless until pioneer agriculture is pushed into these regions. They feed to some extent on green vegetation, but mainly on seeds. As they do not hibernate, they lay up large stores of winter food in their burrows. They are gregarious but, being noctural in their activities, are seldom seen by day.

In the sand-hill and sagebrush country of the West there is much complaint of destruction of pioneer crops by kangaroo rats. The areas first cultivated are usually small, and the animals sometimes destroy an entire crop. Where corn is planted they take all the seed, securing not only food for present use, but storing in their caches large

[1] *Perodipus* and *Dipodomys*. [2] Genus *Microdipodops*.

quantities for the future. They are destructive to other grains also and dig up newly planted melon and other seeds. Vegetable gardening is an impossibility where kangaroo rats are abundant. The choice is between making warfare on and destroying the animals or abandoning cultivation. Fortunately they take poisoned grain readily and are easily trapped with baits of this kind. The poison recommended for prairie-dogs is well adapted to destroy kangaroo rats. Trapping with guillotine traps, although successful, is usually too slow to be practicable.

In some instances farmers in the sand-hills of the West prevent depredations by kangaroo rats and succeed in growing crops of corn by stirring the seed in hot water in which there has been mixed enough coal tar to coat the grain slightly. A large spoonful of coal

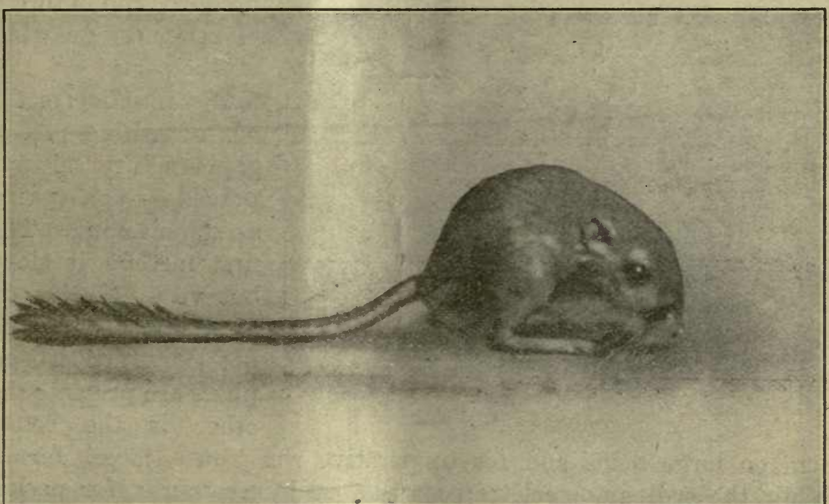


FIG. 4.—Kangaroo rat, adult, one day after capture. B252M

tar to a gallon of boiling water is used. When the mixture has cooled somewhat the corn may be stirred in and allowed to remain several minutes without danger to germination.

POCKET GOPHERS.

Pouched rats, commonly called pocket gophers (fig. 5), are among the most serious of rodent pests in most of the States west of the Mississippi River. They occur also in parts of Georgia, Alabama, and Florida, in the greater part of Illinois, and in southern Wisconsin. Outside the United States they are abundant southward in many parts of Mexico and Central America, and northward in northwestern Canada to Winnipeg and the Saskatchewan Valley.

Nine groups, or genera, of pocket gophers are recognized, but only three of them occur north of Mexico. Two of these[1] have a very

[1] *Geomys* and *Thomomys*.

wide distribution. They include many species and varieties, all nearly similar in habits and alike destructive. Many forms inhabit mountains and deserts, where they do not injure agriculture. Others, however, live in the richest alluvial soils, where they are destructive to all crops.

Pocket gophers do harm in many ways. They eat growing grain and cover much of it with soil. In digging burrows they cause loss of hay by throwing up mounds which prevent close mowing. These mounds also injure much machinery. Their burrows admit surface water and aid it to wash out deep gullies on sloping land. By piercing dams and embankments the tunnels cause costly breaks. The animals ruin gardens and injure field crops. In addition to this they kill trees in orchards and in forest plantings by gnawing off the roots.

FIG. 5.—Pocket gopher. B999M

Two practical methods of killing pocket gophers are always possible—trapping and poisoning. The first method is slow, but very effective on small areas or where but few pocket gophers are present; the other is the better plan on large fields and for cooperative work on adjacent farms. While the ordinary steel trap may be used successfully for pocket gophers, much better results can be obtained with the special traps for these animals commonly on the market (fig. 6).

In irrigated districts, where water is available, flooding the land will drive out the animals, and they may be killed by men and dogs. Fumigation of the burrows with carbon bisulphid or with sulphur smoke, while often recommended as a means of destroying pocket gophers, has been found extremely uncertain and costly.

Poison for pocket gophers.—Cut sweet potatoes or parsnips into pieces with the largest diameter less than an inch. Wash and drain 4 quarts of the cut baits. Place in a metal pan, and from a pepperbox slowly sift over the dampened baits ⅛ ounce of powdered strychnin (alkaloid) and one-tenth as much saccharin (well shaken together or ground together in a mortar), stirring to distribute the poison evenly.

Tunnels of pocket gophers, which are usually from 3 to 8 inches below the surface of the ground, may be readily located by means of a probe. Any blacksmith can make one by affixing a metal point

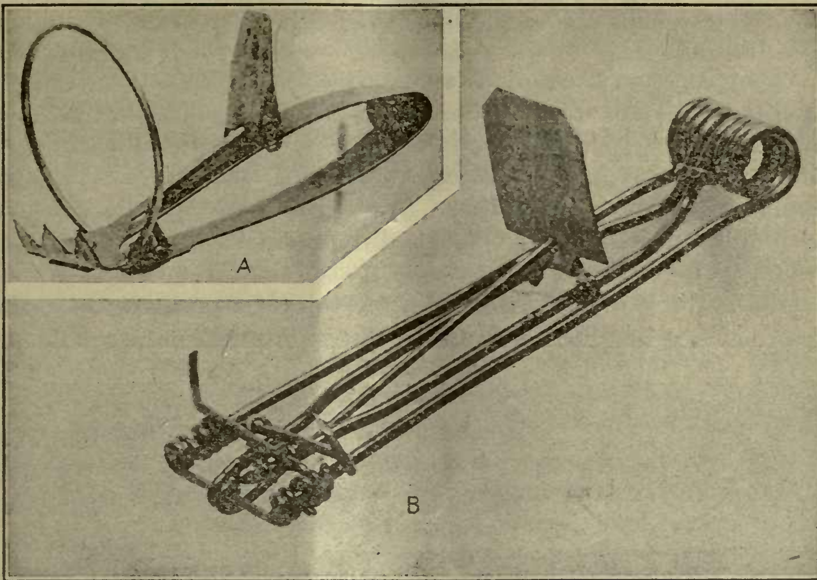


FIG. 6.—Types of special pocket-gopher traps.

to a shovel or spade handle and attaching an iron foot rest about 15 or 16 inches above the point. By forcing this instrument into the soil near the pocket-gopher workings, or a foot or two back of fresh mounds, one can feel the open tunnel as the point breaks into it. The hole may be enlarged and its sides made firm by pressing the soil laterally with the probe. A bait or two should be dropped into the tunnel and the probe hole covered. Care should be taken to place the baits in the main tunnels rather than in the short laterals leading to mounds. Different forms of probes have been used successfully by the Biological Survey in its demonstration work. Two of the better kinds are illustrated in figure 7.

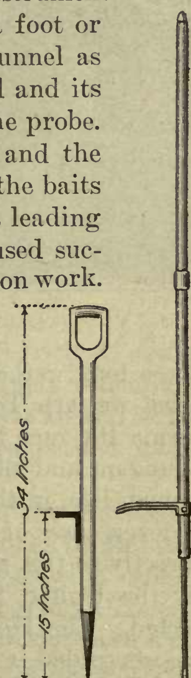


FIG. 7.—Convenient probes for locating pocket-gopher runs.

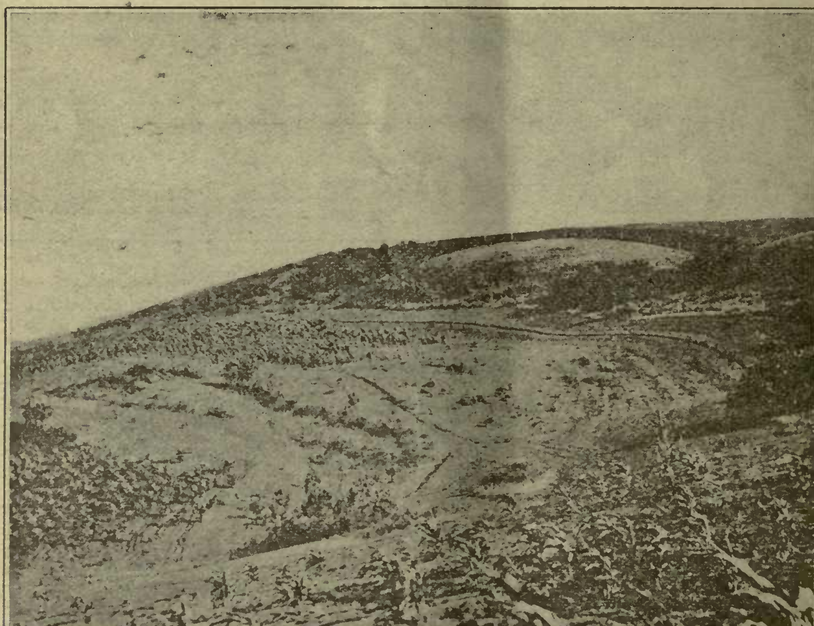
GROUND SQUIRRELS.

More than 50 species and races of ground squirrels, or spermophiles,[1] inhabit the United States and Canada, and some of them are so numerous in agricultural regions as to be a constant menace to the crops. The spermophiles comprise a group of long, slender animals, of grayish or grayish-brown color—sometimes mottled or striped—and with a medium or long tail, usually less bushy than that of the larger of the tree squirrels. These ground squirrels are often, but wrongly, called "gophers" and are locally named "dig-

[1] Genus *Citellus*.

ger" squirrels and "picket pins." They inhabit mainly open plains, mountain valleys, and borders of wet meadows, but are found also in open places in the forests and sometimes high up the slopes of mountains. They dig numerous deep burrows and are very destructive to nearly all crops (figs. 8 and 9), eating both the growing plants and the ripe or ripening grain. In irrigated districts the animals burrow in embankments (fig. 10) and levees and are almost as troublesome as pocket gophers.

Among the largest and most destructive of these animals is the California, or "digger," ground squirrel.[1] It is gray in color and



B9141

FIG. 8.—Cornfield ruined by Columbia ground squirrels (see title-page illustration).

has a long, rather bushy tail. It occurs in the Southwest and West from western Texas to California and Oregon.[2] In parts of California the race known as the Beechey ground squirrel is especially abundant and menaces not only crops and irrigation ditches, but also human life, in that it is a known carrier of bubonic plague. About a dozen cases of this disease among human beings have been traced directly to this squirrel and a large number of the animals collected by the United States Public Health Service have been found infected. The Health Service, in cooperation with State authorities, has succeeded in establishing south and east of San Francisco, in the

[1] *Citellus beecheyi beecheyi* and related races.
[2] Including the closely related *Citellus grammurus*.

counties that were the center of infection, a wide zone now comparatively free from squirrels. The Department of Agriculture, through the Bureau of Biological Survey, has exterminated most of the squirrels in the national forests that lie near the plague-infected counties. It is probable that all immediate danger of an outbreak of human plague by infection from ground squirrels has passed.

Another large and destructive species is the Columbia ground squirrel[1] (see illustration on title-page). It occurs within the United States in parts of Montana, Idaho, eastern Washington, and eastern Oregon. While it inhabits chiefly the river valleys, it has been taken in Montana on mountains near timberline. Where grain is grown

FIG. 9.—Mound of California ground squirrel in oats field. B11132

in the narrow valleys and in the important wheat districts of eastern Washington this species is extremely injurious. Early attempts to destroy it by poison proved unsuccessful, because the animal is able to resist much larger doses of strychnin than are needed to kill other ground squirrels.

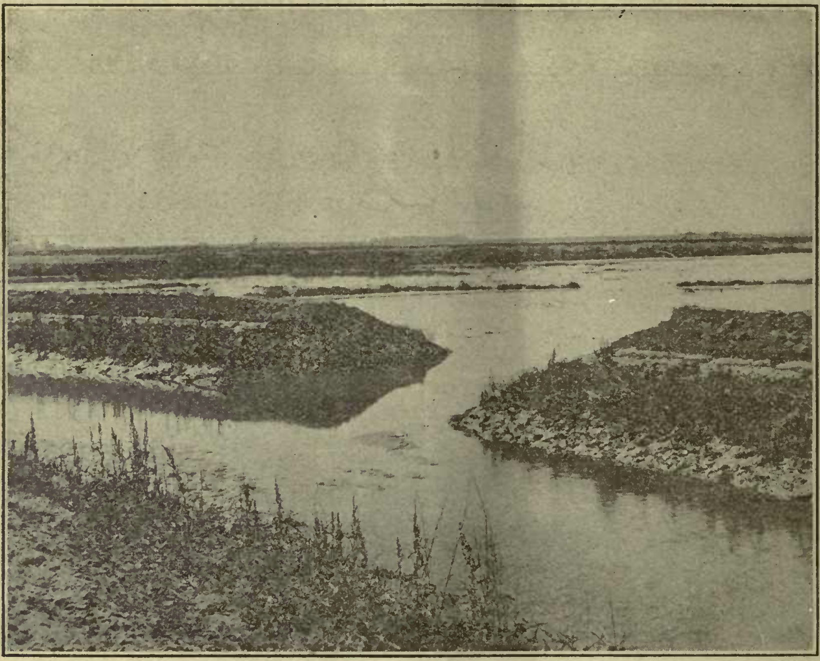
A destructive and widely distributed species is the Richardson ground squirrel.[2] In its larger form it is found in much of Montana, the Dakotas, and northward into Canada. A somewhat smaller race (*elegans*) is found in southeastern Oregon, northern Nevada, southern and eastern Idaho, southern Wyoming, and northern Colorado. This spermophile is very destructive to crops, especially to

[1] *Citellus columbianus.*

[2] *Citellus richardsoni richardsoni* and *Citellus richardsoni elegans.*

grain, and within its range warfare against it is absolutely necessary to successful farming.

The striped ground squirrel,[1] the Franklin ground squirrel,[2] and some other species, which are less gregarious and seldom occur in great numbers in any locality, are less destructive than any of the three groups named. Other species are nearly as injurious as those described. The animals have been dealt with in three groups, because slightly different formulas for poisoning each of them have been worked out by field investigators of the Biological Survey. The



B11148

FIG. 10.—Break in irrigation ditch (lateral) caused by burrowing of California ground squirrel. Six acres of alfalfa ruined.

formula for the Richardson ground squirrel is adapted for all the species except the Columbia and the California forms.

Poison for Columbia ground squirrels.—Mix 1 ounce of powdered strychnin (alkaloid), 1 ounce of powdered bicarbonate of soda, 1 teaspoonful of saccharin, and ½ pound of dry powdered laundry starch, and stir with enough cold water to make a smooth, creamy paste. Apply to 12 quarts of good, clean oats in a metal tub or other vessel, and stir thoroughly to distribute the poison evenly. When the poisoned grain is dry scatter it along squirrel trails or on hard soil on the surface near the squirrel burrows. A quart of the grain should make 40 to 50 baits, and if properly distributed stock will not be endangered by this quantity.

[1] *Citellus tridecemlineatus,* including several races.
[2] *Citellus franklini.*

Poison for Richardson ground squirrels.—Mix 1 tablespoonful of laundry starch in ½ teacup of cold water, and stir it into ½ pint of boiling water to make it a thin, clear mucilage. Mix 1 ounce of powdered strychnin with 1 ounce of powdered bicarbonate of soda, and stir the mixture into the hot starch, making a smooth, creamy paste free from lumps. Stir in ¼ pint of heavy corn sirup and 1 tablespoonful of glycerin, and, finally, 1 scant teaspoonful of saccharin. Apply to 20 quarts of oats, and mix thoroughly to coat every kernel. Each quart of the poisoned grain should make 40 to 60 baits. Distribute in same manner as stated for poisoning Columbia ground squirrels.

Poison for California, or "digger," ground squirrels.—Prepare by same formula as for Richardson ground squirrels, but use 16 quarts of clean barley instead of oats. Distribute as for poisoning Columbia ground squirrels.

These poisons may be used at any time of the year when the squirrels are active. The Biological Survey has had excellent results with them, even in midsummer. Trapping is too slow a process to use effectively against large colonies of ground squirrels.

B 14282

FIG. 11.—Prairie-dog.

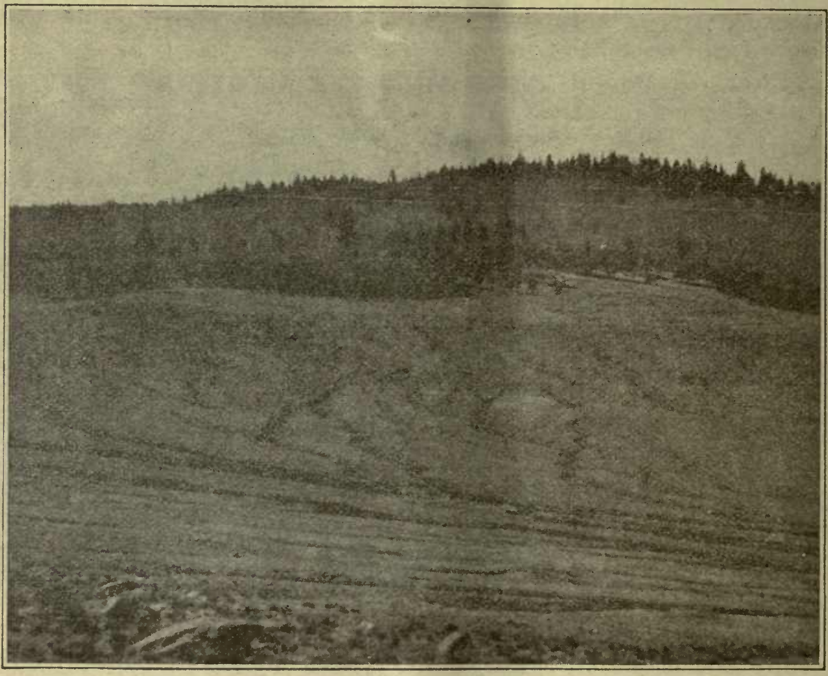
PRAIRIE-DOGS.

The prairie-dog[1] (fig. 11) of the Great Plains needs little description. It is widely distributed on the plains east of the Rocky Mountains, from northern Mexico almost to the Canadian border. Several other forms occupy the mountain valleys and parks westward. All live in thickly populated colonies, or "towns," and subsist on vegetation. They often take fully half the pasturage on the ranges and greatly reduce the carrying capacity for live stock (fig. 12). Several Western States have attempted to provide for the extermination of prairie-dogs through legislative enactments; and in some of them, notably Kansas, the pest has greatly decreased. Within the national forests settlers have complained of inability to cope with the animals, because their lands when freed from prairie-dogs are reinfested from the surrounding Government lands. For this reason and for range improvement the Department of Agriculture has undertaken systematic extermination work within the forests and has already succeeded in freeing large areas of these animals.

[1] *Cynomys ludovicianus.*

Trapping is too slow a method for exterminating prairie-dogs, and fumigation is too expensive. As in the case of ground squirrels, strychnin has proved to be the most satisfactory poison. Oats of the best quality obtainable should be used as bait. It has been found that prairie-dogs take this grain readily, even when green food is abundant. Wheat is well adapted for winter poisoning, and in the South, where heavy oats are rarely obtainable, milo or feterita is an excellent substitute.

Poison for prairie-dogs.—Mix thoroughly 1 ounce of powdered strychnin (alkaloid) and 1 ounce of common baking soda (bicarbonate). Dissolve 1 heaping tablespoonful of dry laundry starch in a little cold water and add it



B14233

FIG. 12.—Erosion following the destruction of grass by prairie-dogs.

to ¾ pint of boiling water. Boil and stir until a thin, clear paste is formed. Slowly sift the mixture of strychnin and soda into the starch paste, stirring constantly to form a smooth, creamy mass. Add ¼ pint of heavy corn sirup and 1 tablespoonful of glycerin, and stir. Add $\frac{1}{10}$ ounce of saccharin, and again stir thoroughly. Pour this mixture while still hot over 13 quarts of clean oats and mix until all the grain is coated.

If alkaloid strychnin is not available, the sulphate may be used, either powdered or in crystals, but it is necessary to vary the formula. Dissolve the strychnin in the boiling water before adding the cold starch. After the poisoned starch paste is clear, stir in the soda very slowly. Then add the sirup, glycerin, and saccharin as in the above directions and mix with the grain.

For mixing small quantities an ordinary metal washtub is convenient. For large quantities a tight, smooth box may be used, and the mixing done with a hoe or spade.

Each quart of the prepared grain is sufficient to treat about 50 prairie-dog burrows. Scatter the grain on clean, hard ground near the mounds or burrows, never on loose soil or in the holes. With reasonable care, cattle, sheep, or other live stock on the range will not be endangered.

This poison is effective at any season when prairie-dogs are active, but, on the whole, early spring or a time of drought, when green food is scarce, is preferred for poisoning operations. In the South, or wherever the animals do not hibernate, winter poisoning is recommended. The cost of complete extermination of the animals, including labor, need not exceed 4 or 5 cents an acre.

B18066

FIG. 13.—Woodchuck, known also as marmot and ground-hog.

WOODCHUCKS.

The woodchuck, or ground-hog, is the largest of our marmots. The common woodchuck (fig. 13)[1] inhabits eastern North America from northern Georgia and middle Alabama northward, including the greater part of Canada. In the United States it ranges westward to Arkansas, eastern Kansas, and eastern Minnesota. In Canada it is found as far north as Great Slave Lake and westward to the base of the Rocky Mountains. Another species of woodchuck[2] inhabits the higher country of the Black Hills, Rocky Mountains, Sierra Nevada, Cascades, and other ranges in the West. This mountain form seldom comes in contact with agriculture, but the eastern species frequently damages garden vegetables, clover, and other crops. Also, its burrows and mounds interfere with mowing and other farm operations. In some States the animal is regarded as so obnoxious that local bounties are paid for destroying it.

Woodchucks, while somewhat gregarious, seldom occur in large colonies, and may, therefore, be kept in check by shooting or trapping. They may be poisoned by strychnin inserted in pieces of sweet apple, carrot, or sweet potato. The animals are often destroyed in

[1] *Marmota monax monax* and several geographic races.

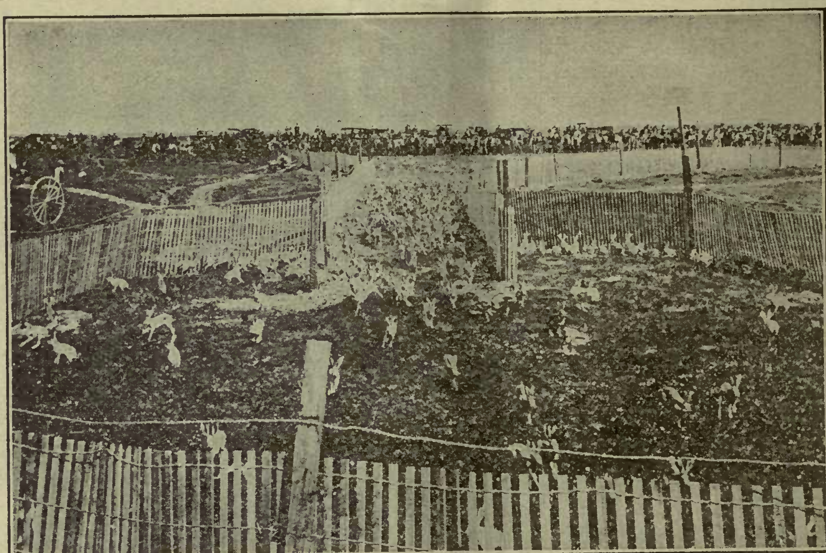
[2] *Marmota flaviventris flaviventris* and nearly a dozen races.

their burrows by fumigation with carbon bisulphid or by the discharge of blasting powder.

To destroy woodchucks with carbon bisulphid, saturate a wad of cotton or waste with about 1½ ounces of the liquid. Place the cotton well inside the woodchuck burrow and close the opening with a piece of sod, well stamped down. If there are two or more entrances to a burrow, all but one should be tightly closed before fumigation.

RABBITS.

The smaller forms of rabbits, known generally as cottontails,[1] are useful animals and become objectionable only when too numerous in



B73M

FIG. 14.—An organized rabbit drive. Community cooperation in hunting jack rabbits gives very good results in rendering the numbers of these animals, everywhere regarded as a pest.

the vicinity of orchards or nurseries. The same is true of the larger snowshoe rabbits.[2] The jack rabbits[2] of the West are of less value for human food, and, by reason of their abundance in newly settled regions, often interfere greatly with crops and the growing of orchard and other trees.

Jack rabbits are not protected in any of the States, but are everywhere regarded as a pest. They afford considerable sport in coursing with fleet greyhounds, and at times become so abundant and destructive that entire communities unite to kill them by the organized hunt or drive (fig. 14). A large area is surrounded, and the animals are driven toward some central point, where a wire corral

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[1] Genus *Sylvilagus*. [2] Genus *Lepus*.

has been built, into which, with the help of wing barriers, thousands of rabbits are driven and then slaughtered. When these hunts take place in cold weather the rabbits are usually shipped to large cities, where the carcasses may be sold to canning establishments, distributed to public charities, or otherwise used to supplement the meat supply.

Many of the States which have a close season for cottontail or other native rabbits permit landowners at any time to protect property from the depredations of the animals. Usually, however, close hunting and trapping in the open season afford ample protection, and only in exceptional cases is it necessary to resort to other measures for relief.

Except where deep snows fall, orchards or other crops on small areas may be protected by the use of rabbit-proof fencing. Individual trees may be safeguarded by metal or wooden protectors attached to the trunks. In Idaho a poisoned wash of strychnin, glycerin, and starch proved effective to save trees from jack rabbits, and the method is recommended for trial in any locality where conditions warrant its use. The wash is prepared as follows:

Poison wash.—Dissolve 1 ounce of strychnin (sulphate) in 3 quarts of boiling water. Dissolve ½ pound of laundry starch in 1 pint of cold water, stirring thoroughly. Pour the starch into the vessel containing the strychnin and boil the mixture a short time until the starch is clear. Add 6 ounces of glycerin and stir. When the paste is cool enough apply to tree trunks with a paint brush.

The mixture adheres well and forms a thin coating. If rabbits attack the tree they will be killed before they can seriously injure it. The wash should not be used if live stock, especially young cattle, have access to the orchard.

For poisoning jack rabbits in winter the following formula is recommended:

Poison baits.—Good oats, 12 quarts; powdered strychnin, 1 ounce; laundry starch, 1 tablespoonful; soda (bicarbonate), 1 ounce; saccharin, ⅛ ounce; water, 1 quart. Prepare as directed for mixing prairie-dog poison. Not over a tablespoonful of the poisoned grain should be used in a single bait, and this should be scattered considerably. A little alfalfa hay may be used to attract rabbits to the grain. The poison is especially effective when snow covers the ground.

Partly ripened or ripe heads of barley or wheat soaked in a sweetened solution of strychnin or coated with the starch-strychnin paste just described have also proved effective bait for rabbits, but care must be exercised in using them, as they are likely to be eaten by live stock.

OTHER NATIVE RODENTS.

Other native rodents that occasionally damage crops or other property are the muskrat, mountain-beaver (fig. 15),[1] woodrats,[2] tree

[1] Genus *Aplodontia*. [2] Genus *Neotoma*.

squirrels, chipmunks, and perhaps some species of native mice not already mentioned. Muskrats are valuable fur animals and should not be destroyed unless they are doing material damage not otherwise preventable. They are easily trapped or may be poisoned by feeding them pieces of carrot, sweet apple, or sweet potato in which strychnin has been placed.

Mountain-beavers in the United States are restricted to the coastal region of Washington, Oregon, and California, and to the Sierra Nevada in the last-named State. Their habitat does not often bring them in contact with agriculture, but in western Washington considerable complaint of their depredations on crops, particularly small fruits, has been made. The animals may be readily poisoned with apples in which strychnin has been placed.

B15902

FIG. 15.—Mountain-beaver, or sewellel, a pest in parts of the Northwest.

Squirrels, chipmunks, and native mice not previously mentioned rarely do serious damage. If any become troublesome locally, shooting, trapping, or the use of poisons herein recommended for other rodents will prove satisfactory means of relief.

INTRODUCED RODENTS.

The house mouse and three kinds of rats are the only rodent pests in North America not native to the country. They are our most injurious rodents, however, and probably inflict greater losses than do all the native species combined.[1]

House mice are easily trapped or poisoned, but poison is not suited for use in occupied dwellings. Traps, however, are sufficiently effective for clearing the premises of these pests. The ordinary small guillotine traps are recommended. They should be set as lightly as possible and baited with oatmeal (rolled oats). A few grains should be placed on the trigger pan and a little more in the vicinity and close to the trap. Persistent trapping will soon clear an ordinary dwelling of mice.

[1] For a full discussion of these rodents, see Farmers' Bulletin 896, "House Rats and Mice," 1917.

Rats are much more suspicious than mice and are rather hard to trap or poison. Either method of destroying them may be made effective by making inaccessible all food other than the baits used. The importance of rat-proofing buildings in extensive operations against these pests should not be overlooked; and much loss may be prevented by rat-proofing all containers of stored grains and food products. No one kind of poison can be relied upon to be effective under every circumstance. In general, poisons can not be used in occupied dwellings without disagreeable results, for no poison will prevent decomposition of dead bodies of rats. Inside of residences, therefore, traps must be the main reliance. Simple traps of the guillotine type are recommended as best. Baits should be varied to suit local conditions—in meat markets grains are recommended, and where grain is stored meat and fish are more effective.

Some cats and some dogs are useful against rats, but the well-fed and pampered feline or canine will refuse to hunt them. Ferrets are of no use in rat catching unless handled by an experienced person helped by trained dogs. Rat viruses seldom prove satisfactory, and in occupied premises are open to the same objections that hold against poisons; besides, they are much more expensive.

Under most circumstances the best results in ridding premises of rats may be obtained by the use of a sufficient number of ordinary guillotine traps. Oatmeal is recommended for bait, but fish, bacon, sausage, and even pastry or cheese are sometimes useful as alternatives. Traps should be set lightly, and all food other than baits should be covered or made inaccessible. Traps may be placed in runs, behind furniture or boards leaned against the walls, or at the entrances to rat holes. As they are often sprung when rats run over them, they need not always be baited. It is needless to say that in order to succeed, the trapper must take an interest in his work and attend closely to every detail.

RELATION OF CARNIVOROUS ANIMALS TO RODENTS.

Most carnivorous, or flesh-eating, animals feed extensively on the rodent pests of the farm. Coyotes, foxes, wildcats, badgers, skunks, minks, and other flesh-eating mammals are among the most potent agents in preventing an undue increase of mice, ground squirrels, pocket gophers, and the like; and much of the damage now done by rodents is due to the unceasing warfare that has been waged against their enemies, the carnivorous animals. These have been hunted, not only for their valuable pelts, but because they are considered the enemies of domestic animals and game. The fact that many of them destroy far more noxious rodents than they do useful animals has often been forgotten, and, in the name of game protection, legislatures have sometimes proscribed by bounties species that do far more good than harm. As a matter of fact many of our fur animals are an asset to the country, equally as valuable as our game, and experience has often proved that their destruction is no real help to game conservation.

Birds of prey, including eagles, hawks, and owls, may be included in the list of flesh-eating animals that on the whole are more useful than harmful, because their chief economic function is to destroy noxious rodents. A few species of hawks that feed mainly on small birds should be considered noxious, but this should not lead to warfare against hawks as a class. In almost every instance of depredation on poultry by either bird or mammal, the individual and not the species is the offender. Punishment should, therefore, be directed against the individual. It is within the law in many States for the farmer to kill an animal that destroys his property; but it is unjust to carry on an offensive campaign against all hawks or all minks because one has been a marauder on poultry. The payment of money from the public treasury in a general warfare against certain hawks or owls is especially open to danger, in that the public does not distinguish between species, and the useful ones are often the ones to be destroyed.

Snakes also are extremely useful in controlling the numbers of rodents. That very few snakes are venomous is too often forgotten, and all species are wantonly destroyed. People throughout the country should acquaint themselves with the habits of snakes and learn the folly of killing them; farmers, especially, should do all in their power to protect the harmless kinds.

COOPERATION IN CONTROLLING RODENTS.

Any farmer may by care and industry free his own premises of harmful rodents, but he is helpless to prevent an early recurrence of the trouble unless he can secure the active cooperation of his neighbors.[1] Only by unity of effort can an entire county or township be freed of any kind of rodent that may inflict losses on crops or other property. By combining to hire labor and purchase poison the cost of treatment may be materially reduced, and when permanance of results is considered there can be no question of the economy of such cooperation. It is urged, therefore, that wherever possible the destruction of rodent pests be made a community undertaking.

In the past, individual efforts, often supplemented by the payment of bounties by State, county, or township, have accomplished so little to reduce rodent depredations that other methods are now required. In many western counties the sum paid out in a single year

[1] Cf. Separate No. 724, from the Yearbook of the Department of Agriculture for 1917, entitled "Cooperative Campaigns for the Control of Ground Squirrels, Prairie-Dogs, and Jack Rabbits," by W. B. Bell.

for bounties on pocket gophers or ground squirrels would, if wisely expended in poisoning operations, secure the destruction of every such animal in the county and make unnecessary any further outlay for the purpose. The bounty system affords no permanent relief from rodent pests and entails heavy taxation as long as it is continued.

The Bureau of Biological Survey has developed effective methods of destroying field mice, pocket gophers, ground squirrels, prairie-dogs, and other noxious rodents. These have been applied over wide areas and their effectiveness fully demonstrated. The work has been done on public lands by the bureau alone or elsewhere in cooperation with other bureaus or with State or county authorities. A wide extension of these activities is planned, and correspondence or conference on the subject is invited.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO NOXIOUS MAMMALS.

AVAILABLE FOR FREE DISTRIBUTION.

How to Destroy Rats. (Farmers' Bulletin 369.)
The Common Mole of Eastern United States. (Farmers' Bulletin 583.)
Field Mice as Farm and Orchard Pests. (Farmers' Bulletin 670.)
Cottontail Rabbits in Relation to Trees and Farm Crops. (Farmers' Bulletin 702.)
Trapping Moles and Utilizing Their Skins. (Farmers' Bulletin 832.)
House Rats and Mice. (Farmers' Bulletin 896.)
Cooperative Campaigns for the Control of Ground Squirrels, Prairie-Dogs, and Jack Rabbits. (Separate 724, Yearbook for 1917.)
The House Rat: The Most Destructive Animal in the World. (Separate 725, Yearbook for 1917.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

Some Common Mammals of Western Montana in Relation to Agriculture and Spotted Fever. (Farmers' Bulletin 484.) Price 5 cents.
Meadow Mice in Relation to Agriculture and Horticulture. (Separate 388, Yearbook 1905.) Price 5 cents.
Pocket Gophers as Enemies of Trees. (Separate 506, Yearbook 1909.) Price 5 cents.
The Jack Rabbits of the United States. (Biological Survey Bulletin 8.) Price 10 cents.
Coyotes in Their Economic Relations. (Biological Survey Bulletin 20.) Price 5 cents.
Economic Study of Field Mice, Genus *Microtus*. (Biological Survey Bulletin 31.) Price 15 cents.
Directions for the Destruction of Wolves and Coyotes. (Biological Survey Circular 55.) Price 5 cents.
Destruction of Deer by the Northern Timber Wolf. (Biological Survey Circular 58.) Price 5 cents.

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The Spotted Garden Slug

WM. H. WHITE
Scientific Assistant
Truck Crop Insect Investigations

FARMERS' BULLETIN 959

UNITED STATES DEPARTMENT OF AGRICULTURE

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

WASHINGTON, D.C.
JUNE, 1918

GARDENERS, MUSHROOM GROWERS, AND TRUCKERS frequently observe irregular holes in the foliage of such crops as lettuce, tomato, peas, and beans, either grown under glass or in the open, and mushrooms from which holes have been cut as by a mouse or rat. By close observation a glistening whitish substance will be seen on the plants or near by, and search under stones, old boards, and rubbish will disclose the cause of the injury—the garden slug.

Attack is most severe on delicate seedlings, but various tubers and roots are subject to injury. Potatoes are bored into and celery is frequently damaged during the bleaching process.

Garden slugs are not insects, although their injury is similar and they are sometimes called insects. They are mollusks and therefore related to the snails, although they have no external shell.

This bulletin describes the habits and development of the spotted garden slug and explains how to rid the premises or grounds of this destructive and otherwise undesirable tenant. The standard remedies for this and the other injurious garden slugs are lime, finely powdered salt, road dust, or other powders. Poisoned baits consisting of boiled potatoes or sweet potatoes sprinkled with arsenic are useful. The garden and greenhouse should be kept clean and free from rubbish and the slugs should be collected at night when they emerge from their hiding places.

THE SPOTTED GARDEN SLUG.[1]

CONTENTS.

PLANTS AND PLANT PARTS INJURED.

THE SPOTTED GARDEN SLUG (fig. 1) in recent years has attracted considerable attention by its depredations in gardens, greenhouses, and mushroom beds. Its fondness for fungi makes it a serious pest when once it has gained access to a mushroom house. In a greenhouse its attack usually is confined to young, tender seedlings, but ornamentals are rendered unsightly and unsalable by the trail of mucus which exudes from the animal's body, as it crawls from place to place. It frequently is abundant in gardens, especially in cool, damp seasons; often causing serious loss to growers of such plants as celery, lettuce, peas, and beans.

WHAT THE SLUG LOOKS LIKE.

The spotted garden slug is one of the largest land mollusks of its kind and often attains a length of 7 inches when fully extended.

[1] Thirty-two species of garden slugs have been reported for the United States. Of these, four are introduced forms. Most of the native species are comparatively harmless so far as their ravages on crops and gardens are concerned. The conditions produced by the opening of the land for agricultural pursuits have effected decided hardships and forced them into the background. The larger west American slugs, however, some of which attain almost a foot in length, are occasionally an exception to this rule.

The real pests of our gardens, cellars, and wells are three introduced species, the spotted garden slug, *Limax maximus* L., ably discussed in this bulletin; the tawny garden slug, *Limax flavus* L., which is a smaller species rarely attaining a length of over 4 inches, and readily distinguished from the larger spotted garden slug by having the body of a more or less uniform dusky yellow shade with obsolete lighter yellowish spots and a tawny yellow shield and bluish tentacles, and the true garden slug, *Agriolimax agrestis* L. The last is probably the greatest pest of all the slugs in our country at present. It is a much smaller species, scarcely exceeding an inch and a half in length and much more often scarcely attaining an inch. It varies from uniform whitish through pale ochraceous, sometimes to lavender, purplish, or even almost black, with mottlings and specklings of various shades of brown. This little form, on account of its small size, can hide away in crevices to a much greater extent than the larger species, and therefore it is exceedingly abundant in city gardens, where it outnumbers the larger forms probably by 20 to 1. This may be considered the most important of the destructive slugs in our country at the present time. On account of its smaller size it has been transported more frequently to the interior than the other two species, which at the present are still largely distributed coastwise.

The remedies suggested for the destruction of the spotted garden slug will apply to any of the American species as well as to the other introduced forms. It may be well to add that, in the case of cisterns, wells, and cellars, sulphur fumigation has proved effective.—PAUL BARTSCH.

The individuals more generally found range in length from $1\frac{1}{2}$ to 4 inches. The slug varies in color from a more or less yellowish gray or brown, mottled with black, to uniform dark gray and black. Usually three uninterrupted rows of black spots extend from the mantle, or shield-like covering on the fore part of the back and sides, to the hind end of the body (fig. 1). The younger forms usually are uniform in color. The mantle is yellowish, marked with black spots. The large breathing opening is situated on the right side near the base of the mantle. The long, stout "horns," or peduncles, which are thrust forward when the slug is in motion, bear the black eyes at the tip. A sticky mucous secretion exudes from the body of the creature.

FIG. 1.—The spotted garden slug, full grown. About natural size.

HISTORY AND DISTRIBUTION.

The spotted garden slug was first described in 1758 by Linnaeus, who found it in shaded places and woods. Its first appearance in the United States does not seem to be definitely recorded, but its occurrence in New England extends over a period of upwards of 50 years. The species is widely distributed, being known all over Europe, in Asia Minor, Corsica, Sicily, Sardinia, the Azores, Madeira, New Zealand, and the United States. It is more abundant along the Atlantic and Pacific coasts than in the interior of the United States.

FOOD AND HAUNTS.

This slug attacks plants of many kinds. Its favorite foods are fungi and stored tubers, but it is also fond of raw beef and sour milk. It has been recorded as feeding on lettuce (fig. 2), celery, tomato, parsnip, carrot, strawberry, beet, turnip, cabbage, onion, leeks, melons, beans, peas, white potato, sweet potato, and common grasses. It displays considerable fondness for the foliage of violets.

The spotted garden slug thrives in dark and damp locations, such as those under old decaying boards and logs, under board walks, in cellars and creameries, along hedgerows, and beneath damp refuse.

NATURE AND EXTENT OF INJURY.

The slug injures the plant by gnawing large irregular holes in the leaves or by cutting off the stems, and by leaving after it a trail of sticky mucus on the plants and along the ground. Injury to mushrooms (fig. 3) is especially severe, the large holes cut by the slug ruining them for the market. Potatoes, both Irish and sweet, when

FIG. 2.—Work of the spotted garden slug on lettuce.

stored in damp, cool cellars, are also subject to attack. The slug is not content to feed on one tuber until that is entirely destroyed, but will pass from one to another, nibbling small holes in the potatoes near the edge of the pile or container. Celery in the beds during the bleaching process often harbors large numbers, which seriously damage the stems.

HABITS.

Soon after emerging from the eggs the young slugs move about in search of food. This consists of such material as is near at hand, since the young do not wander far. They remain four or five weeks in a colony in the location where the eggs were deposited. The slugs remain under cover until nightfall and then come out to feed. The "homing" instinct is well developed in this species, and these slugs will return to the same place night after night unless disturbed, or unless the place becomes too dry for habitation. During their nocturnal excursions they shun all dry, dusty, or sharp surfaces. The route of the slugs back to their daily abode usually is the same as that taken when going forth. When full grown the slugs will travel long distances and overcome many obstacles in search of their favorite food. In confinement these creatures will attack one another, and when the weaker succumbs its body is devoured.

FIG. 3.—Work of the spotted garden slug on mushroom.

DESCRIPTION.

THE EGG.

The eggs are deposited in masses, held together by a light-colored substance, in moist places, such as under decaying boards, flowerpots, and refuse. Sometimes they are placed beneath the surface of the ground under clods of earth.

The translucent, light yellow eggs, with tough and elastic outer membrane, usually will be found in masses of from 50 to 70, though the writer has found 106 in one mass, and one female has been known to deposit 112 eggs in two days.

THE SLUG.

The newly hatched slug when extended is a little less than half an inch long and about one-seventh as wide as long. It is dull white, showing no coloration except where the dark eyestalks can be seen through the transparent mantle. In a few hours after hatching the mantle begins to darken, and in about two days the whole body of the animal has turned still darker, three broken longitudinal lines appearing, which run from the base of the mantle to the hind end of the body. The mantle then changes to a mottled gray. As the animal feeds it becomes of a darker and darker hue until in about a month it is dark brown and the black spots begin to appear. In some cases these spots, which are arranged in a line, disappear and the body is of a solid color. These black spots may or may not reappear. When full grown the slug is nearly 7 inches in length.

DEVELOPMENT.

The writer has found freshly deposited egg masses at all times from spring until fall. In a greenhouse or other structure which is heated during the cold months the females deposit their eggs the year round.

The incubation period varies with the temperature and moisture. In an atmosphere of from 60° to 70° F. the eggs hatch in about 28 days, but if the temperature is higher the young will appear in a shorter time.

The young slugs develop slowly, feeding very little in the younger stages. In 30 days they attain a length of about an inch. This growth, however, depends upon the abundance of food and upon the weather conditions. The slug is capable of living on very little food, but during such times growth is slow.

The exact time required by the animal to attain full growth is not known, but slugs held in captivity and reared from eggs made a growth of 2 inches in six months. These slugs were reared in a greenhouse and were supplied with an abundance of food.

HIBERNATION.

The spotted garden slug undoubtedly spends the winter below the frost line in the ground, in drain pipes, cellars, greenhouses, and pits, on well walls, and along foundations. The writer has never found any during the colder winter months in exposed places, such as under boards, or in any of the old haunts of summer. Slugs which were exposed to a temperature below freezing soon succumbed.

NATURAL ENEMIES.

Among the slug's few natural enemies is the common toad.

HOW TO ABATE THE SLUG NUISANCE.

ARSENICALS PARTIALLY EFFECTIVE.

Owing to its habit of feeding by night and concealing itself during the day, the spotted garden slug is very difficult to control. It will avoid food of a coarse nature.

The application of arsenicals to the plant is impractical, chiefly because attack is local and the creatures avoid most poisoned substances. The use of poisoned baits is not entirely satisfactory because of the slowness of the slug to change its diet unless this becomes necessary to prevent starvation. The methods of control to be used vary according to the location in which the slugs feed and the nature of the food plant. In mushroom beds it is not practical to employ a poisoned bait because the slug prefers fungi to all other foods.

Where large plants are being injured poisoned baits may be employed with fair results. For this purpose baked or boiled white potatoes sprinkled with white arsenic have been found effective. This bait should be placed so that one potato will be in about 2 square feet of the affected area. Inferior potatoes are quite as useful as sound ones, and large tubers or roots should be sliced.

CONTROL BY CLEAN METHODS.

Wherever this pest occurs cleanliness will accomplish much toward its riddance.

Slugs may be kept under control in the mushroom house, first, by a thorough cleaning and then by a careful examination of all the material taken into the house to make certain that no slugs or eggs are attached to it. Old boards and the edges of the compost pile may harbor eggs or young, and these should be examined carefully before they are carried into the house.

COLLECTING SLUGS AT NIGHT.

After slugs have become established in a greenhouse they should be sought out at night with a lantern or pocket flashlight. The slugs at this time may be found feeding or crawling about in search of food. At such times they can be easily collected and destroyed. In the daytime they may be traced to their retreats by the trail of slime which they leave behind. Loose boards and débris lying about should be turned over and examined for eggs and young slugs.

THE USE OF LIME AND SALT.

Lime is the standard remedy for slugs, and salt and soot are efficient.

In a mushroom house the slugs can be prevented from gaining access to mushrooms by a border about 2 inches wide of lime, salt, road dust, soot, or any cheap powder, placed around the edges of the beds. When the slug touches this substance it will wriggle into the material. This causes it to secrete slime copiously and soon it exhausts itself and dies.

In the greenhouse slugs are more difficult to control, because there is a wider range for their activities and their hiding places are more numerous and not readily located. Young seedling beds should be protected by a border of such substances as are recommended in the case of mushrooms. In the case of potted plants each pot should be taken out and examined before the border of repellent is placed around it, as such pots are among the favorite haunts of the young slugs.

TREATMENT IN THE FIELD.

When abundant in the field or garden the slug is even more difficult to control than in the mushroom house or greenhouse, and the only solution of the problem consists in thoroughly cleaning up the hiding places of the pest, around the edges of the garden, under old boards and stones, and in any place that is cool and moist. These places should then be sprinkled with lime, and where practicable lime should be applied directly to the area and plants on which the slugs are feeding. In time this will drive them away.

O

A little work in the garden in the fall of the year may add greatly to the results secured from the efforts put forth during the following spring and summer.

PREVENTING FRUIT TREE INJURY BY FIELD MICE

W. C. DUTTON, HORTICULTURAL SECTION

Field mice frequently cause severe losses to fruit growers by girdling trees. Such injury is more often found on young trees and usually only when there is some material around the tree which makes a good harboring place for the mice. A heavy growth of a cover crop or a mulch of straw around the trees makes an attractive place for field mice to work. Injury is very common in neglected young orchards where there is a heavy growth of grass and weeds.

Many paints and washes have been recommended to prevent such injury. Some of them are poisons and others simply repellents. During the winter of 1918 and 1919 the experiment reported here was planned to test several of these materials.

Materials.

Several of the more commonly recommended poisons and repellents were used. The materials and the strengths at which they were used are listed below.

1. Concentrated commercial lime-sulphur.
2. Concentrated commercial lime-sulphur with slaked lime to make a rather thick wash.
3. Concentrated commercial lime-sulphur and lead arsenate.
4. Sulfocide (a proprietary material).
5. Whitewash.
6. Whitewash and lead arsenate.
7. Strong bordeaux mixture.
8. Check. No treatment.

The concentrated lime-sulphur was used at full strength. Enough lead arsenate was used to make a strong poison. The mixtures contained much more poison than is ever used for spraying purposes. Sulfocide was not diluted. The whitewash and other mixtures with which lime was used were made of about the same consistency as rather thick cream. The bordeaux mixture was made by the 10-10-50 formula and then thickened with slaked lime.

The Trees.

Large sized nursery trees, three years old, were used for this work. The variety was Wagener. Seven or eight trees were painted with each material and eighteen trees were left untreated as checks. The materials were applied with a brush and the entire trunk was covered from the roots up to a point above where any injury would occur. Each tree was labeled to indicate the material used on it. The trees were set in the ground in two groups between the rows in an orchard of dwarf apples. This orchard was heavily mulched. They were set in rows, with the trees about one foot apart in the row and were distributed so that those treated with any particular material were not grouped together. After setting, the trees were well mulched with straw and cornstalks. They were set on February 15. There was no frost in the ground at that time.

Results.

On May 7th the mulch was removed and the trees examined. The trees were classified according to the degree of injury or the lack of injury. A tree was classified as "slightly injured" if only a small spot on one side had been chewed by the mice. Any injury worse than this was classed as "severe." The number of trees in each class is listed

	Total No. Trees	Trees injured by mice		No. Injury
		Severely	Slightly	
Lime-sulphur	8	7	1	0
Lime-sulphur and lime	8	4	2	2
Lime-sulphur and lead arsenate	7	6	1	0
Sulfocide	7	7	0	0
Whitewash	8	5	1	2
Whitewash and lead arsenate	8	7	1	0
Thick Bordeaux	7	1	5	1
Check	18	13	4	1

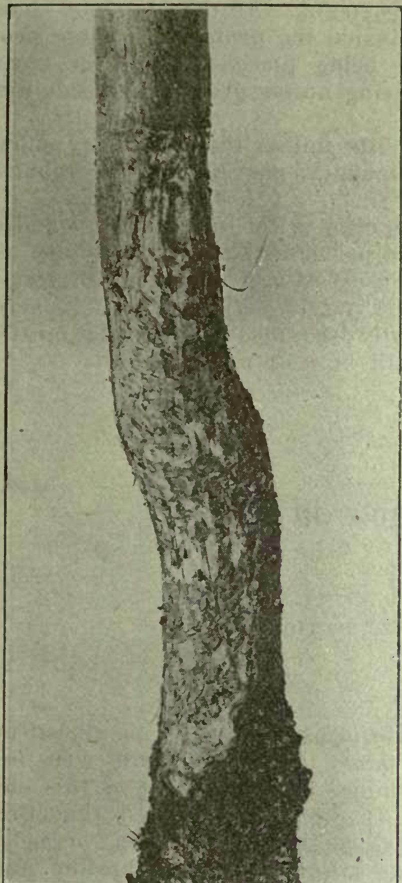
in the accompanying table. These figures show that the injury was very severe on every lot of trees regardless of the material used. The lot of trees painted with thick bordeaux was injured least but there was so much injury even on these trees that its use is not recommended.

Recommendations.

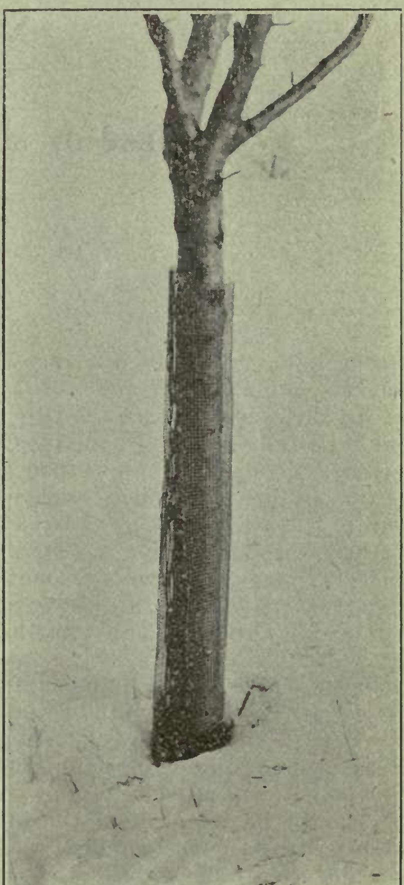
None of the materials used in this experiment are recommended for use on fruit trees to prevent injury by field mice. Better results might be secured by frequent applications but the expense for labor and materials would probably be greater than for good wire protectors. The application of any of these materials would also be difficult when there is snow around the trees as it would be necessary to cover the trunk of the tree to the ground. Field mice will work under the snow and the injury is usually close to the ground.

Wire Protectors

A very satisfactory protector can be made from quarter-inch square mesh galvanized wire netting. Bands not less than eighteen inches in width should be placed around the tree trunk. They should lap enough



A ycung apple tree girdled by field mice.



Desirable type of tree protector. It is made of ¼ inch square mesh galvanized wire netting.

DUSTING AND SPRAYING EXPERIMENTS

OF

1918 AND 1919

BY W. C. DUTTON

INTRODUCTORY

This bulletin contains reports of the results of a series of dusting and spraying experiments conducted by the Horticultural Section during the seasons of 1918 and 1919. This work included comparisons of dusting materials, lime-sulphur solution, bordeaux, dry lime-sulphurs, lead arsenate, calcium arsenate and magnesium arsenate. These materials were used on apples, cherries, plums, peaches, currants and potatoes.

EXPLANATORY NOTES

The meaning of several terms used may not be familiar to all. To avoid repetition, the following explanations are in order:

DUSTING TERMS

90-10 mixture. A dusting mixture containing 90% dusting sulphur and 10% dry lead arsenate.

85-15 mixture. One containing 85% sulphur and 15% lead arsenate.

3 in 1 dust. A mixture containing sulphur, tobacco dust and lead arsenate.

50-40-10 mixture. One containing 50% sulphur, 40% filler (usually hydrated lime) and 10% lead arsenate.

Concentrated dust. A mixture containing only sulphur and lead arsenate. Usually made by the 85-15 or 90-10 formula.

Dilute dust. A mixture containing 40 to 50% sulphur, 35 to 50% filler (hydrated lime, talc or gypsum) and 10 to 15% lead arsenate.

SPRAYING TERMS

1 to 40. This refers to lime-sulphur of 31 to 33 degree Beaume test used at the rate of 1¼ gallons in 50.

4-4-50 bordeaux. This refers to bordeaux made of 4 pounds stone lime (or 6 pounds hydrated lime), 4 pounds copper sulphate and 50 gallons water.

GENERAL TERMS

Check plot or tree. Trees or plants which are left untreated to indicate the amount of injury by insects or disease that would develop when not sprayed or dusted.

Count trees. In much of the work, particularly with apples, the fruit from one or more trees in each plot was sorted and classified according to the presence of any injury by insect or disease or by its freedom from such injury. Trees were selected for this purpose that were as uniform as possible. Location of the tree and the size and uniformity of the crop were points considered in selecting them. The number of trees in any plot was in no case limited to the trees from which counts were actually made. The total number in a plot varied from nine to fifty or more.

Pink or cluster application. The application made on apples just before the blossoms open, but after the buds have separated in the cluster.

Calyx application. In the work here reported the calyx application was usually made immediately after the petals had fallen. It could be safely delayed a few days and still control the coddling moth but earlier application insures better control of apple scab.

Other Insects. This term is used in several of the tables showing results of work with apples. This means injury to the fruit by any chewing insect other than coddling moth, such as the lesser apple worm, Tussock moth, fruit worms, etc.

Calcium arsenate. The same as arsenate of lime or arsenate of calcium.

ACKNOWLEDGMENTS

Much of this work was done at several places in the state in orchards belonging to fruit growers. The Horticultural Department is indebted to these growers for their assistance and co-operation in carrying on this work. They are Geo. Winegar & Son, Morrice; B. F. Hall, Belding; Oscar Braman, Grand Rapids; C. W. Garlock, Grand Ledge; James Boyce, Holland; J. C. Maynard and Ed. O'Brien, Grand Rapids. Much of the actual work with experiments on the College grounds was done by Harold Lackey. The duster used at the College was furnished by the Corona Chemical Company, Milwaukee, Wisconsin. R. E. Loree and M. M. Brown assisted in securing records in 1918. The picture on the front cover is used by the courtesy of D. F. Fisher of the United States Department of Agriculture.

EXPERIMENTS WITH APPLES

The work done with apples in 1918 was largely a comparison of the dusting and spraying methods of application. Tests were also made with calcium arsenate and Sherwin-Williams dry lime-sulphur.

In 1919 the work consisted mainly of tests of the dry lime-sulphurs and of several arsenicals. Some dusting was also done.

EXPERIMENTS IN 1918

COMPARISONS OF DUSTING WITH SPRAYING AND CALCIUM ARSENATE WITH LEAD ARSENATE AT MORRICE

In the orchard at Morrice, belonging to Geo. Winegar and Son, dusting and spraying experiments were continued. Experimental work had been carried on in this orchard during 1915, 1916 and 1917. The results of this earlier work have already been published.* The entire

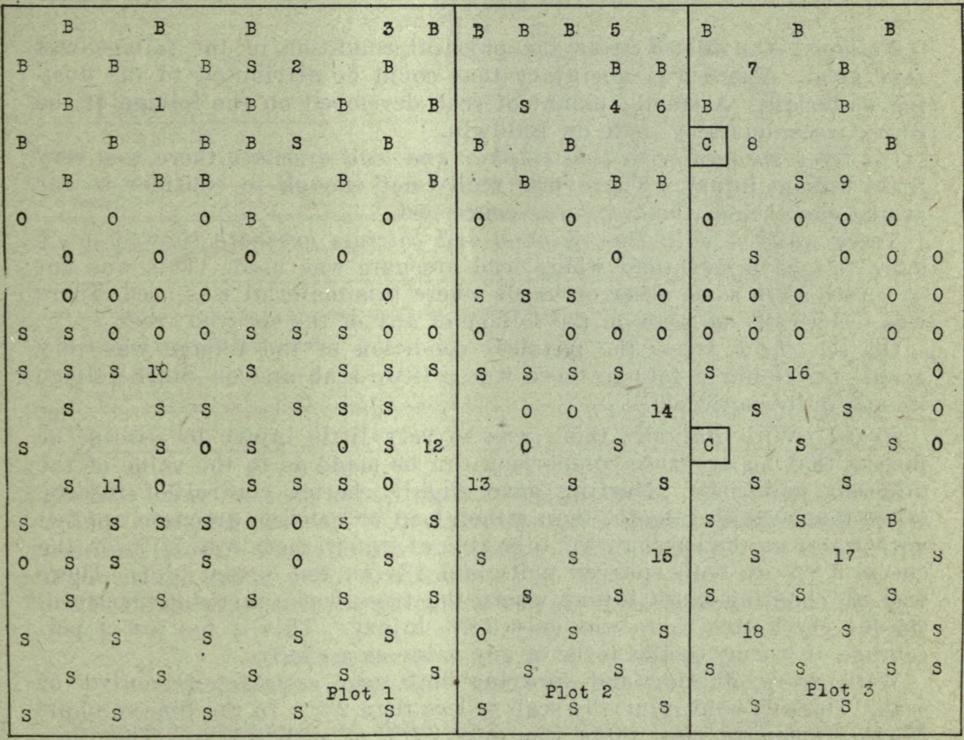


CHART I. Diagram showing arrangement of trees and plots in the Winegar orchard at Morrice. B, Baldwin; S, Stark; C, check; O, other varieties. The numbers indicate count trees. Plot 1, dusted; Plot 2, sprayed with lime-sulphur and calcium arsenate; Plot 3, sprayed with lime-sulphur and lead arsenate.

*Special Bulletin No. 87. Dusting and Spraying Experiments with Apples.

orchard was used, but trees of any variety other than Stark and Baldwin were not considered in the results.

Materials. The orchard was divided into three plots with check trees for each variety. They were arranged so that both Stark and Baldwin were included in each plot. The arrangement of trees and plots is shown in Chart I. The different plots were treated as follows:

Plot 1. Dusted. 90-10 mixture.
Plot 2. Sprayed. Lime-sulphur, 1 to 40 and calcium arsenate (dry), 1 lb. in 50 gal.
Plot 3. Sprayed. Lime-sulphur, 1 to 40 and lead arsenate (paste), 2½ lbs. in 50 gal.

Applications. The four regular application were made at the following periods:

1st. Pink or cluster application.
2nd. Calyx application.
3rd. Sixteen days after second.
4th. August 1st.

RESULTS

Foliage. On *dusted* trees the physical condition of the foliage was very good. There was no injury that could be attributed to the dusting materials. A small amount of scab developed on the foliage of the Stark trees, but very little on Baldwin.

On trees *sprayed* with *lime-sulphur and lead arsenate* there was very little foliage injury. There was really not enough to consider so far as the effect upon the trees was concerned.

Trees *sprayed* with *lime-sulphur and calcium arsenate* showed much more foliage injury than where lead arsenate was used. This was not so severe as in some other orchards where this material was used. There was practically no scab on the foliage of any of the sprayed trees.

On the *check* trees, the physical condition of the foliage was very good. On Baldwin foliage there was a little scab and on Stark foliage it was quite noticeable.

Fruit. With *Baldwin* there was so very little injury by disease or insects that no accurate comparison can be made as to the value of the different materials. Dusting gave slightly better control of insects, other than coddling moth, than either lead or calcium arsenate applied with water as the carrier. Of this type of injury there was 7.5% on the check, 3.8% on both sprayed plots and 1% on the dusted plot. There was no coddling moth injury where the trees were dusted or sprayed. On the check tree there was only 3.8% injury. This is too low a percentage of wormy apples to be of any value as a check.

With *Stark,* dusting and spraying both gave satisfactory control of scab. Dusting held injury by scab to less than 2%. In the lime-sulphur-calcium arsenate plot, there was only 2.5% of scab injury. The lime-sulphur-lead arsenate plot showed 5.4% of scabby fruit. This was probably due, in part at least, to part of the count trees being in lower

TABLE I.—RESULTS WITH BALDWIN AT MORRICE, 1918.

Treatment.	No. of Trees in Plot.	Count Tree Number.	Total No. Apples.	Sound. Per cent.	Scab. Per cent.	Codling. Per cent.	Other Insects. Per cent.
Dusted	26	1	3563	98.88	0.39	0	0.73
		2	3679	98.15	0.78	0	1.06
		3	4873	97.66	0.98	0	1.35
Totals	....	......	12115	98.16	0.75	0	1.08
Sprayed Lime Sulphur and Calcium Arsenate	13	4	3929	93.63	1.78	0	4.58
		5	3565	96.52	0.39	0	3.08
		6	1968	95.93	0.35	0	3.71
Totals	....	......	9462	95.20	0.96	0	3.83
Sprayed Lime Sulphur and Lead Arsenate	11	7	6035	94.86	1.72	0	3.41
		8	4574	94.95	0.80	0	4.24
		9	2745	95.70	0.36	0	3.93
Totals	....	......	13354	95.06	1.13	0	3.80
Check	1	C	2282	87.42	1.14	3.85	7.58

TABLE II.—RESULTS WITH STARK AT MORRICE, 1918.

Treatment.	No. of Trees in Plot.	Count Tree Number.	Total No. Apples.	Sound. Per cent.	Scab. Per cent.	Codling. Per cent.	Other Insects. Per cent.
Dusted	58	10	3853	97.69	1.81	0	0.49
		11	3595	98.38	1.00	0.02	0.58
		12	2437	95.65	3.48	0	0.94
Totals	....	......	9885	97.54	1.93	0.01	0.63
Sprayed Lime-Sulphur and Calcium Arsenate	21	13	2666	93.92	3.37	0.15	2.55
		14	2351	94.51	1.99	0.08	3.44
		15	2802	96.71	2.31	0	0.963
Totals	....	......	7819	95.10	2.58	0.07	2.25
Sprayed Lime-Sulphur and Lead Arsenate	26	16	1535	93.81	4.36	0.06	1.82
		17	1849	92.37	6.16	0.21	1.24
		18	4077	92.61	5.32	0.36	1.74
Totals	....	......	7461	92.80	5.33	0.26	1.63
Check	1	C	1229	52.31	16.48	27.50	5.45

ground. For insects, other than coddling moth, all materials gave nearly complete control. All materials gave almost perfect control of coddling moth. The amount of injury—27.5%—on the check tree was high enough for a good comparison.

The tabulated results of all counts are given in Tables I. and II.

COMPARISON OF DUSTING WITH SPRAYING AND CALCIUM ARSENATE WITH LEAD ARSENATE AT MUIR

Work was continued at Muir in the Northern Spy orchard belonging to Mr. Oscar Braman. The principal object of this work was to get further information as to the effect of the different materials on the foliage.

S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
S	1	2	S	S	S	S	S	S	S	S	S	S	S	S	S
S	S	S	S	S	S	T	S	S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S	S	S	3	S	S	S	S	S
													Plot 1		
S	S	S	S	S	S	S	S	S	S	S	S	4	S	S	S
S	S	S	S	S	S	S	S	S	S	C	S	S	S	S	S
													Plot 2		
S	S	S	S	S	S	S	5	S	S	S	S	S	S	S	6
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

CHART II. Diagram showing arrangement of trees and plots in the Braman orchard at Muir. S, Northern Spy; C, check; T, water tank. Numbers indicate count trees. Plot 1, sprayed with lime-sulphur and lead arsenate; Plot 2, sprayed with lime-sulphur and calcium arsenate. The entire orchard of 40 acres, except Plots 1 and 2 was dusted.

Materials. The main part of the orchard was dusted by Mr. Braman. A block of 36 trees near the middle of the orchard was used for the spraying materials. One of these trees was left untreated as a check. The block of 36 trees was divided into two plots and treated as follows:

Plot 1. Lime-sulphur, 1 to 50, and lead arsenate (dry), 1½ lbs. in 50.
Plot 2. Lime-sulphur, 1 to 50, and calcium arsenate, 1 lb. in 50.
Plot 3. This included the entire orchard other than Plots 1 and 2.

For the first two applications, a 3 in 1 mixture was used and for the last two an 85-15 mixture was used. The arrangement of the trees and plots is shown in Chart II.

Applications. Four applications were made on all plots. They were made at the following periods:

1st. Pink or cluster application.
2nd. Calyx application.
3rd. Two weeks after second.
4th. First week in August.

The spraying was done with a spray gun. 200 to 225 lbs. pressure was maintained. All dusting was done at night, except the last application, by Mr. Wolverton, the man directly in charge of the orchard. For each application, material was applied to one side of each row during one night and to the opposite side the next night. The fourth application was made in the same manner, only during calm periods in day time.

RESULTS

Foliage Injury. The foliage on all *dusted* trees was in excellent physical condition and free from disease.

The foliage of the trees in the *lime-sulphur-lead arsenate* plot was injured some, but not seriously. Only a small percentage of the leaves showed any injury. There was no disease.

The foliage of trees in the *lime-sulphur-calcium arsenate* plot was severely injured by the calcium arsenate, but not badly enough to cause many leaves to drop during the summer. There was no disease on these leaves.

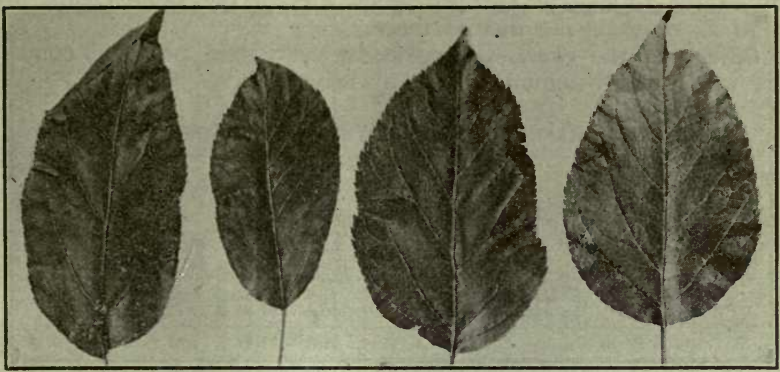


FIG. 1. DUSTED. Typical leaves from Northern Spy trees dusted with sulphur and lead arsenate. They are vigorous and free from injury.

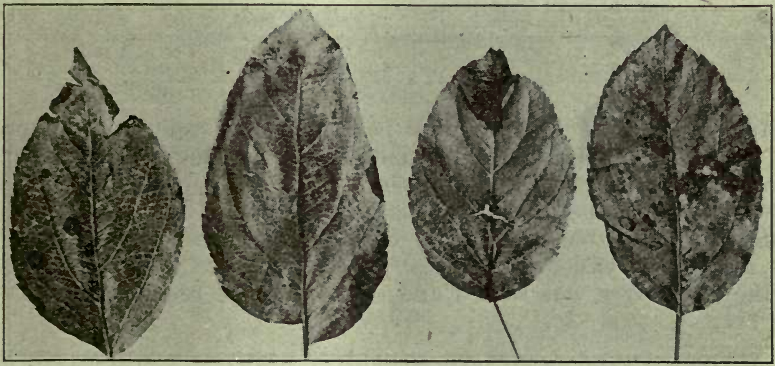


FIG. 2. CALCIUM ARSENATE. Typical leaves from Northern Spy trees sprayed with lime-sulphur and calcium arsenate. There was considerable arsenical injury.

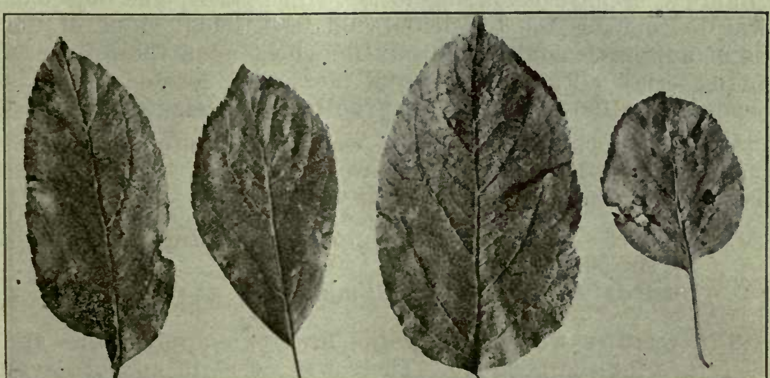


FIG. 3. LEAD ARSENATE. Typical leaves from Northern Spy trees sprayed with lime-sulphur and lead arsenate. There was some injury but not so severe as where calcium arsenate was used.

None of the foliage of *sprayed* trees was in the same clean, bright condition as that on the *dusted* trees.

The foliage of the *check* trees was in very good physical condition. There was a small amount of scabby leaves.

TABLE III.—RESULTS WITH NORTHERN SPY AT MUIR, 1918.

Treatment.	No. of Trees in plot.	Count Tree Number.	Total No. Apples.	Sound. Per cent.	Scab. Per cent.	Leaf Roller. Per cent.	Codling. Per cent.	Other Insects, Per cent.
Dusted	Entire orchard except 36 trees	1 2	1006 1096	96.32 94.54	2.49 1.27	0.79 2.46	0.20 0.27	0.20 1.46
Totals			2104	95.39	1.85	1.66	0.24	0.86
Lime-Sulphur and Lead Arsenate	18	3 4	1538 2118	95.90 93.81	0.39 1.04	3.64 5.05	0 0.05	0.64 0.05
Totals			3656	96.69	0.77	4.46	0.03	0.05
Lime-Sulphur and Calcium Arsenate	17	5 6	7535 1027	97.07 94.55	0.51 2.43	2.22 3.02	0 0	0.19 0
Totals			2562	96.06	1.29	2.54	0	0.17
Check	1	C	540	88.33	5.93	5.56	0	0.18

Fruit. Because of the very low percentage of scabby apples on the check tree, no comparison can be made as to the fungicidal value of the different materials. The same is true with regard to insects. There is some difference in the amount of leaf roller injury, but this is probably due more to a spotted infestation than to the insecticide used.

The fruit from two dusted trees, two trees in each sprayed plot and from the check tree was sorted and counted. The results are shown in Table III.

A COMPARISON OF DUSTING WITH SPRAYING AT BELDING.

A comparison was again made of dusting and spraying at Belding in the Baldwin orchard belonging to Mr. B. F. Hall. The object of this work was to compare the fungicidal and insecticidal value of the two methods of application, also to study the effect upon the foliage of the different materials. The experimental plots were located in the southeast corner of the 100-acre orchard. The trees are eighteen years old.

Materials. A block of eighty trees was divided into two plots. One plot was dusted and the other one sprayed. A tree was left untreated as a check. The plots were treated as follows:

Plot 1. Sprayed. Lime-sulphur, 1 to 40, and lead arsenate (dry), 1¼ in 50.

Plot 2. Dusted. 85-15 and 3 in 1 mixtures.

The 85-15 mixture was used for the first two applications and the 3 in 1 mixture for the last two. There was no 85-15 mixture available for these applications. All the dusting materials were furnished by Mr. Hall. The arrangement of the plots is shown in Chart III.

B	B	B	B	B	B	B	B	B
B	B	B	B	3	B	B	B	B
B	1	2	B	B	4	B	B	B
B	B		B	B	B	C	B	B
B	B	S	B	B	B	B		B
	Sprayed							
B	B	B		S	B	S	B	B
B	5	B	B	B	B	B	B	B
B	B		B	6	B	B	B	B
B	B	B	B	7	B	S	S	S
B	8	S	B	B	B	S	S	S
	Dusted							
B	B	B	B	B	B		B	B

CHART III. Diagram showing arrangement of trees and plots in the B. F. Hall orchard at Belding. B, Baldwin; C, check; S, small trees. Numbers indicate count trees.

Applications. Four applications were made as follows:

1st. The pink or cluster application.
2nd. The calyx application.
3rd. Two weeks after second.
4th. First week in August.

The dusting was done with a large power duster. The trees were dry when all dusting was done, except for the last application. The trees were wet from a light shower which fell just before the dusting was done. The spraying was not always done uniformly as the sprayer frequently did not maintain a satisfactory pressure.

RESULTS.

Foliage. On *dusted* trees there was no foliage injury but a very small amount of scab.

On *sprayed* trees there was no scab but a small amount of foliage injury. The injury was very slight.

On the *check* there was no injury but some scab.

TABLE IV.—RESULTS WITH BALDWIN AT BELDING, 1918.

Treatment.	No. of Trees in Plot.	Count Tree Number.	Total No. Apples.	Sound. Per cent.	Scab. Per cent.	Codling. Per cent.	Other Insects. Per cent.
Sprayed Lime-Sulphur and Lead Arsenate..............	33	1	1315	89.58	9.20	0	1.29
		2	1915	90.28	9.39	0	0.57
		3	1031	90.59	8.92	0	0.48
		4	991	92.73	5.14	0	2.12
Totals..........	....	......	5252	90.63	8.39	0	1.02
Dusted..........	31	5	1144	95.45	2.09	0.96	1.49
		6	1746	96.25	1.87	0.22	1.65
		7	2141	98.36	0.70	0.18	0.75
		8	1272	96.22	2.83	0.08	0.86
Totals..........	....	......	6371	96.81	1.71	0.31	1.16
Check..........	1	C	1324	62.08	36.02	0.53	1.36

Scab control. Dusting gave almost complete control of scab on the fruit. There was only 1.7% of scabby fruit on the count trees. On the *sprayed* trees there was nearly 6% more of scabby apples than on dusted trees. The failure of the sprayer to work satisfactorily at all times was probably responsible for some of the scab on these trees. On the check tree there was 36.0% of scabby apples. This was high enough to give a good check on the treated trees.

Insect Control. There was so little insect injury, on the check tree, that no comparison can be made.

The tabulated results of all counts are given in Table IV.

EXPERIMENTS AT GRAND LEDGE

Spraying experiments were continued in the orchard near Grand Ledge belonging to Mr. C. W. Garlock. The work done there in 1917 has already been reported.* The work here in 1918 was in two parts: (1) a test on Baldwin of Sherwin-Williams dry lime-sulphur and (2) a test of calcium arsenate on Ben Davis.

A TEST OF DRY LIME-SULPHUR ON BALDWIN

Materials. There were three rows of Baldwin trees with ten trees in a row. Each row was used as a separate plot. The dry lime-sulphur was used at two strengths and standard liquid lime-sulphur was used for comparison. The plots were treated as follows:

Plot 1. Sherwin-Williams dry lime-sulphur, 5½ lbs. in 50.
Plot 2. Sherwin-Williams dry lime-sulphur, 3 lbs. in 50.
Plot 3. Liquid lime-sulphur, 1 to 40.

D	D	D	D	1	D	D	S	D	D
							Plot 5		
D	D	S	D	D	4	D	S	2	D
					Plot 4				
S	D	D	D	D	D	3	D	S	C
O	O	O	O	O	O	O	O		O
O	O	O	O	O	O	O	O	O	O
O	O	O	O	O	O	O	O	O	O
							Plot 3		
B	B	5	S	B	6	B	B	B	B
							Plot 2		
B	B	B	7	8	B	B	B	C	B
							Plot 1		
B	B	9	B	B	B	10	B	B	B
O	O	O	O	O	O	O	O	O	O

CHART IV. Diagram showing arrangement of trees and plots in the Garlock orchard at Grand Ledge. D, Ben Davis; B, Baldwin; C, check; O, other varieties; S, small tree. Numbers indicate count trees. Plot 1, Sherwin-Williams dry lime-sulphur, 5½ in 50; Plot 2, Sherwin-Williams dry lime-sulphur, 3 in 50; Plot 3, dilute lime-sulphur; Plot 4, calcium arsenate; Plot 5, lead arsenate

Lead arsenate (dry) was used on all plots at the rate of 1¼ pounds in 50 gallons. The arrangement of the plots and trees is shown in Chart IV.

*Special Bulletin No. 87. Dusting and Spraying Experiments with Apples.

The results from the use of dry lime-sulphur on Northern Spy in 1917 were not so satisfactory as where the standard lime-sulphur solution was used. It was thought at that time that if the amount used in each fifty gallons was increased so as to contain the same amount of actual sulphur as is found in 1¼ gallons of standard lime-sulphur solution, that the results would be better. Accordingly, it was used at two rates in 1918. First, at the rate of 3 pounds in 50 gallons, which is the maximum strength recommended by the manufacturers, and second, at the rate of 5½ pounds in 50 gallons. This gave about the same amount of sulphur as would be found in 1¼ gallons of lime-sulphur solution testing 32 degrees Beaume.

Application. Four applications were made as follows:

1st. Pink or cluster application.
2nd. Calyx application.
3rd. Two weeks after second.
4th. First week in August.

All spraying was done with a spray gun and with high pressure.

RESULTS

Foliage Injury. There was very little foliage injury in any plot. The foliage of trees sprayed with *dry lime-sulphur* was in slightly better condition than where the standard *lime-sulphur solution* was used, but the injury was so slight in any case that it was of little importance.

TABLE V.—RESULTS WITH BALDWIN AT GRAND LEDGE, 1918.

Treatment.	No. of Trees in Plot.	Count Tree Number.	Total No. Apples.	Sound. Per cent.	Scab. Per cent.	Codling. Per cent.	Other Insects. Per cent.
Standard Lime-Sulphur Solution	9	5	1852	94.38	0.32	0.54	4.75
		6	2644	93.04	1.62	0.64	4.69
Totals			4496	93.59	1.09	0.60	4.71
Dry Lime-Sulphur, 3 in 50	9	7	1989	92.11	1.91	0.85	5.13
		8	3100	94.26	2.16	0.55	3.03
Totals			5089	93.42	2.06	0.67	3.85
Dry Lime-Sulphur, 5½ in 50	10	9	1689	93.72	1.18	0.77	4.32
		10	2583	95.97	0.97	0.54	2.52
Totals			4272	95.08	1.05	0.63	3.23
Check	1	C	2116	68.71	7.28	15.93	8.08

Scab Control. The amount of scab on the check tree was so small that no comparison could be made as to the fungicidal value of the different materials. Counts were made on the fruit from two trees in each sprayed plot and from the check tree. The tabulated results of the counts are shown in Table V.

CALCIUM ARSENATE ON BEN DAVIS

Materials. Rex calcium arsenate was used on a small block of Ben Davis to determine its effect on the foliage and its insecticidal value.

FIG. 4. CALCIUM ARSENATE injury on Ben Davis foliage. Defoliation was severe.

FIG. 5. MAGNESIUM ARSENATE injury on foliage of apple.

For comparison, one plot was sprayed with lead arsenate. Check trees were left. The materials were used as follows:

Plot 4. Calcium arsenate (dry), 1 lb. in 50 (no lime).

Plot 5. Lead arsenate (dry), 1¼ lb. in 50.

They were both used in combination with lime-sulphur diluted at the rate of 1 to 40. The arrangement of the trees and plots is shown in Chart IV.

Applications. The four regular applications were made as follows:

1st. Cluster or pink application.
2nd. Calyx application.
3rd. Two weeks after the second.
4th. First week in August.

All spraying was done with a spray gun and with high pressure.

RESULTS

Foliage Injury. The trees sprayed with *lead arsenate* were in good condition. There was very little foliage injury. The foliage of trees sprayed with *calcium arsenate* was severely burned. The leaves were badly spotted and many leaves dropped. The injury was not of the yellow-leaf type.

TABLE VI.—RESULTS WITH BEN DAVIS AT GRAND LEDGE, 1918.

Treatment.	No. of Trees in Plot.	Count Tree Number.	Total No. Apples.	Sound. Per cent.	Scab. Per cent.	Codling. Per cent.	Other Insects, Per cent.
Lead Arsenate with Lime-Sulphur	11	1 2	3093 1072	90.33 97.20	6.24 1.21	2.36 0.56	1.07 1.03
Totals			4165	96.15	1.16	0.83	1.86
Calcium Arsenate with Lime-Sulphur	13	3 4	2730 1837	95.13 97.66	1.65 0.43	0.66 1.09	2.56 0.82
Totals			4567	96.15	1.16	1.86	0.83
Check	1	C	2060	38.13	13.49	46.84	3.34

Insect Control. Both materials gave very good insect control. 46.8% of the apples on the unsprayed tree were affected by codling moth. This gave a good check on the insecticidal value of the different materials. The results of counts are given in Table VI.

EXPERIMENTS IN 1919

The work with apples in 1919 was done in two orchards near Grand Rapids. The work consisted of a comparison of dusting with spraying and testing several dry lime-sulphurs and some of the newer arsenicals.

A TEST OF SULPHUR DUSTS LIME-SULPHUR SOLUTIONS DRY LIME-SULPHURS AND B. T. S.

A Duchess orchard of about 125 trees was used for experimental tests with sulphur dust, lime-sulphur, Sherwin-Williams dry lime-sulphur, Dow dry lime-sulphur and B. T. S. The dry lime-sulphurs and B. T. S. are not applied as a dust, but are dissolved in water and applied as any other spraying material. This orchard is about fifteen years old and is on the fruit farm belonging to Mr. J. C. Maynard. It is located about two miles west of Grand Rapids. There is a number of Wealthy trees in the orchard but they were not used for experimental purposes.

Materials. The orchard was divided into eight plots as shown in Chart V. The plots were treated as follows:

Plot 1. Dusted. 3 in 1 and 90-10 mixtures.
Plot 2. Sprayed. Lime-sulphur solution 1 to 40.
Plot 3. Sprayed. Sherwin-Williams dry lime-sulphur, 3 lbs. in 50.
Plot 4. Sprayed. Sherwin-Williams dry lime-sulphur, 5½ in 50.
Plot 5. Sprayed. Dow dry lime-sulphur, 3 lbs. in 50.
Plot 6. Sprayed. Dow dry lime-sulphur, 5½ lbs. in 50.
Plot 7. Sprayed. B. T. S., 4 lbs. in 50.*
Plot 8. Sprayed. B. T. S., 7 lbs. in 50.

Lead arsenate (dry) at the rate of 1¼ pounds in 50 gallons was used with all spraying materials for all applications. Black Leaf 40 was used on all sprayed plots for the first application.

The dry lime-sulphurs and B. T. S. were used at two rates. First, at the maximum rate recommended by the manufacturers for summer sprayed of apples, and second, at the strength which gives about the same amount of actual sulphur as is contained in one and one-fourth gallons of lime-sulphur solution, testing 32 degrees Beaume. The reason for using these materials at the increased strength has been stated on page 13.

Applications. Three applications were made. The August application was omitted as the fruit was nearly ripe at that time. They were made at the periods listed below:

1st. Cluster or pink application.
2nd. Calyx application.
3rd. Two weeks after second.

The dusting was done with a large power duster. Dusting material was always applied from two directions. The foliage was usually dry when the work was done. The 3 in 1 mixture was used for the first application and the 90-10 mixture was used for the second and third. The spraying was done with spray guns and when the foliage was dry.

RESULTS

Foliage Injury. The foliage of the *dusted* trees was in excellent physical condition. Early in the season a little scab was found but this did not develop further. All *sprayed* trees showed a small amount of foliage injury and the leaves did not have the same clean, bright appearance as on dusted trees. The injury was not severe. There was no noticeable difference in the amount of injury in the different sprayed plots.

*B. T. S. is manufactured by the General Chemical Company. The letters are the initials of the words "barium tetra-sulphide." This is the chemical name of the material.

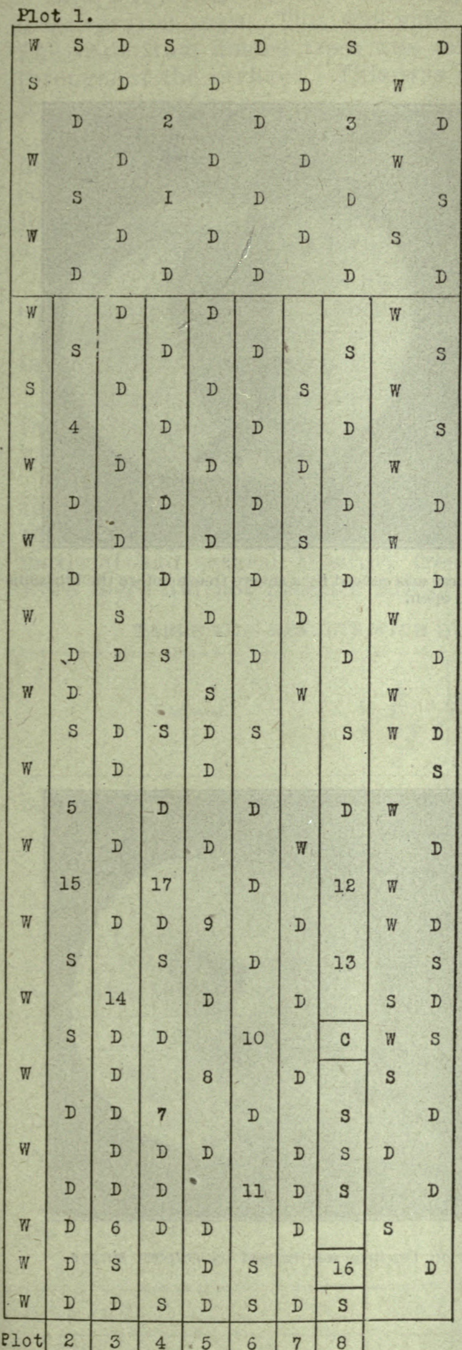


CHART V. Diagram showing arrangement of trees and plots in the Maynard orchard at Grand Rapids. D, Duchess; C, check; W, Wealthy; S, small tree. Numbers indicate count trees. Tree 16 is a check tree. The plots are indicated by the numbers at the top and bottom of the chart.

- Plot 1. Dusted.
- Plot 2. Dilute lime-sulphur.
- Plot 3. Sherwin-Williams dry lime-sulphur, 3 in 50.
- Plot 4. Sherwin-Williams dry lime-sulphur, 5 ¾ in 50.
- Plot 5. Dow dry lime-sulphur, 3 in 50.
- Plot 6. Dow dry lime-sulphur, 5½ in 50.
- Plot 7. B. T. S. 4 in 50.
- Plot 8. B. T. S. 7 in 50.

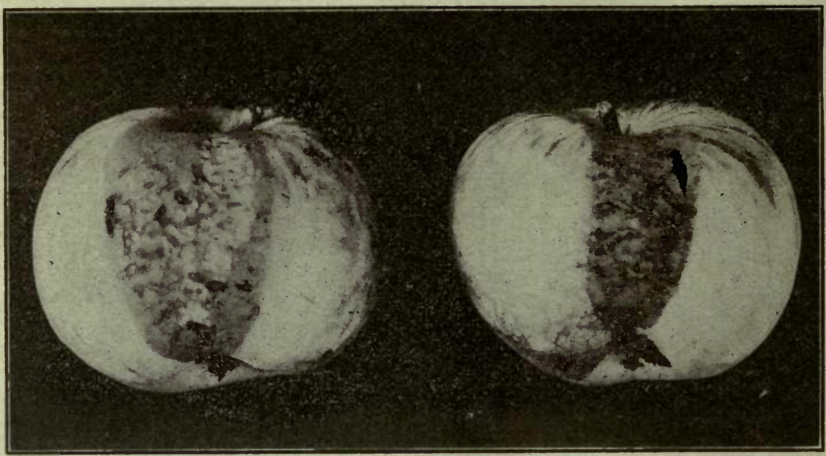


FIG. 6. FROST INJURY. This injury on Duchess was caused by a severe freeze before the blossoms were open.

FIG. 7. SPRAY INJURY. This injury on Duchess was caused by sulphur sprays.

Injury to Fruit. There was a slight russeting found on the fruit from most sprayed trees. This was more noticeable where B. T. S. was used. The fruit from dusted trees was very smooth. Frost injury was found throughout the orchard. This was entirely different from the russeting just mentioned.

Insect Control. There was so little aphis injury on the check that no comparison can be made. *Dusting* and *spraying* both gave very good control of codling moth and other chewing insects. The amount of injury on the *check* trees was not very severe, but there was enough for a check on the different materials.

Scab Control. Sulphur dust and *lime-sulphur solution* gave about equal control of scab. Control in those plots was nearly complete except for an early infection which took place before any dusting or spraying was done. Dusting gave more uniform control than spraying.

The *dry lime-sulphurs* and *B. T. S.* failed in every case to give satisfactory control of scab. The increase in strength of these materials gave very little benefit.

The tabulated results of all counts made are shown in Table VII. In this table no results are given for the plot sprayed with B. T. S. at the rate of 4 pounds in 50 gallons. The row which was sprayed with this material had several Wealthy trees in it and the Duchess trees that were there did not produce full crops, so no counts could be made.

TABLE VII.—RESULTS WITH DUCHESS AT GRAND RAPIDS, 1919.

Treatment.	No. of Trees in Plot.	Count Tree Number.	Total No. Apples.	Sound. Per cent.	Scab. Per cent.	Aphis Per cent.	Codling. Per cent.	Other Insects. Per cent.
Dusted	22	1 2 3	1698 3219 1268	86.63 86.70 88.17	12.77 13.11 11.27	0.11 0 0	0 0 0	0.47 0.19 0.55
Totals			6185	86.98	12.64	0.03	0	0.34
Lime-Sulphur, 1 to 40	11	4 5 15	1320 2046 1956	91.13 79.81 84.15	8.64 19.16 15.44	0 0.10 0	0.07 0.10 0.05	0.15 0.83 0.36
Totals			5322	84.22	15.18	0.04	0.07	0.49
Sherwin-Williams Dry L-S, 3 in 50	17	6 14	1184 1050	64.10 70.19	33.44 29.33	0.51 0	0 0.19	2.03 0.28
Totals			2234	66.96	31.51	0.27	0.09	1.21
Sherwin-Williams Dry L-S, 5½ in 50	12	7 17	1133 667	71.05 85.00	27.54 14.84	0 0	0.18 0.15	1.23 0
Totals			1800	76.22	22.83	0	0.16	0.78
Dow Dry L-S, 3 in 50	15	8 9	3214 3482	60.42 61.57	38.52 37.33	0 0	0.09 0.08	0.96 1.01
Totals			6696	61.02	37.90	0	0.09	0.98
Dow Dry L-S, 5½ in 50	11	10 11	1773 2146	63.06 64.54	36.60 34.29	0 0	0 0.19	0.33 0.97
Totals			3919	63.87	35.34	0	.10	0.69
B. T. S., 7 in 50	7	12 13	1708 1018	78.81 64.93	20.43 34.77	0 0	0 0	0.76 0.29
Totals			2726	73.62	25.79	0	0	0.59
Check	2	16	1153	21.59	62.36	3.72	9.97	27.67

FIG. 8. APPLE BLOSSOM BUDS. This shows the stage of development of the buds when the "pink" or "cluster" application is usually made.

FIG. 9. APPLE BLOSSOM BUDS. If the buds remain in this stage for several days because of cold weather and conditions are favorable for scab development, an extra application will probably be profitable. It should be followed by the regular cluster application.

In comparing the percentages of scabby fruit on any of the plots it will be well to consider the following facts. In the spring the blossom buds opened slightly, just enough so that the individual buds could be easily distinguished, and remained in this condition for a week or more because of cold weather. During this period conditions were very favorable for scab development. No dusting or spraying was done until the buds had separated into the cluster stage.

When the fruit was harvested and counted, there was found on the apples from all plots an early infection of scab. This scab was in small spots which were on or partly on the calyx lobes. On fruit from the dusted plot there was very little scab of any later infection. On fruit from the plot sprayed with lime-sulphur solution there was a small amount of scab on other parts of the apples. In all the dry lime-sulphur and B. T. S. plots there was much more on other parts of the apples. The later infections had nearly always developed with larger spots.

This early infection undoubtedly occurred before the first application was made. On the plots treated with sulphur dust and lime-sulphur solution there was very little scab of any later infection. This condition indicates two things: (1) an early or "pre-pink" application would have prevented the early infection of scab and (2) sulphur dust and lime-sulphur solution prevented practically all development of later infections but the dry lime-sulphur and B. T. S. did not.

A TEST OF SEVERAL ARSENATES ON APPLES

A block of mature Stark trees was used for testing several arsenates. This block of Stark trees is part of an orchard of several varieties belonging to Mr. A. D. O'Brien and is located about three miles west of Grand Rapids.

Materials. The block of trees was divided into four plots of about nine trees each and each plot was sprayed with a different poison. The materials and the strengths at which they were used are listed here:

Plot 1. Corona calcium arsenate (dry), 1 lb. in 50 gal. with 3 lbs. hydrated lime added.
Plot 2. Corona lead arsenate (dry), 1¼ lbs. in 50 gal.
Plot 3. Dow magnesium arsenate (dry), 1¼ lbs. in 50 gal.
Plot 4. NuRexform lead arsenate (dry), 1¼ lbs. in 50 gal.
Two trees were left unsprayed as checks.

Lime-sulphur solution, diluted at the rate of 1 to 40, was used in combination with all the poisons, for all applications. Black Leaf 40 was used on all plots for the first application. The arrangement of the trees and plots is shown in Chart VI.

Applications. Four applications were made according to the regular schedule.

1st. The pink or cluster application.
2nd. Immediately after petals had fallen.
3rd. Two weeks after second.
4th. July 30th.

All spraying was done with a spray gun and with 200 to 225 pounds pressure.

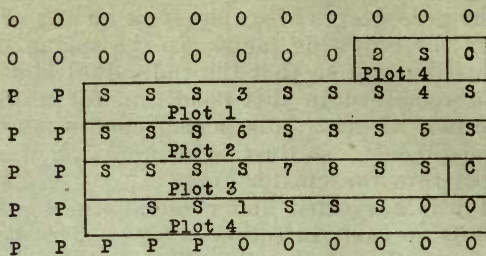


CHART VI. Diagram showing arrangement of trees and plots in the O'Brien orchard at Grand Rapids. S, Stark; C, check; O, other varieties; P, peach tree. Numbers indicate count trees. Plot 4 is in two parts. Plot 1, calcium arsenate; Plot 2, Corona lead arsenate; Plot 3, Magnesium arsenate; Plot 4, Nurexform lead arsenate. The check tree next to the small portion of Plot 4 was used as a count tree.

RESULTS

Foliage Injury. The foliage of all trees sprayed with *lead arsenate*, both Corona and NuRexform, was in very good condition throughout the season. There was very little injury which was traceable to lead arsenate.

The trees sprayed with *calcium arsenate* showed foliage injury but not enough to be classed as serious.

Magnesium arsenate caused very severe foliage injury. This was not evident until after the calyx application. In a few days after this application, many leaves were spotted, turned yellow and dropped. The effects of the injury caused by the calyx application had about passed when the third application was made. The same process of leaves turning yellow and dropping developed again and continued for about two weeks. The same thing happened again after the fourth application. These trees lost fully half their foliage because of the injury by magnesium arsenate.

TABLE VIII.—RESULTS ON STARK AT GRAND RAPIDS, 1919.

Material.	No. of Trees in Plot.	Count Tree Number.	Total No. Apples.	Sound. Per cent.	Codling. Per cent.	Other Insects. Per cent.
Corona Lead Arsenate	9	5 6	3765 2676	97.90 96.45	1.56 2.72	.53 .82
Totals			6441	97.30	2.04	.65
NuRexform Lead Arsenate	7	2 1	4136 3159	97.97 97.06	1.81 2.37	.21 .56
Totals			7295	97.57	2.05	.37
Corona Calcium Arsenate	9	3 4	2313 3553	94.38 93.55	5.44 5.43	.17 1.01
Totals			5866	93.88	5.43	.68
Dow Magnesium Arsenate	8	7 8	1698 2517	85.22 87.48	12.01 11.32	2.76 1.19
Totals			4215	86.58	11.60	1.82
Check	2	C	2284	15.53	81.17	3.45

Insect Control. Both kinds of lead arsenate controlled all insects very satisfactorily. *Calcium arsenate* did not give quite so good control as lead arsenate. *Magnesium arsenate* failed to give satisfactory insect control.

The tabulated results of counts made are given in Table VIII.

SUMMARY OF RESULTS OF EXPERIMENTS WITH APPLES

DUSTING

Scab Control. In 1918 at Morrice the amount of scab that developed on the untreated trees was not very great, but with Stark there was enough to give a satisfactory check on different materials used. The dusting method gave almost complete control of scab, as there was only 1.9% of scabby apples in the dusted plot of Stark. With Baldwin there was only 1.1% of scabby apples on the check tree, so the results with this variety are not conclusive.

At Muir in 1918 with Northern Spy there was so little development of scab on the check tree that no comparison can be made of dusting with spraying.

At Belding in 1918 with Baldwin there was enough development of scab on the check to allow satisfactory comparisons. The dusting method gave nearly complete control of scab and better control than spraying with lime-sulphur solution. Failure of the sprayer to always work satisfactorily probably accounts for part of the scab on the sprayed plot.

In 1919 at Grand Rapids dusting gave better control of scab on Duchess than spraying with lime-sulphur solution. The difference, however, was very small.

Insect Control. In part of the experiments there was so little insect injury on the check trees that no safe comparisons can be made. This is true of the work in 1918 with Baldwin at Morrice and Belding and with Northern Spy at Muir. With Stark at Morrice there was considerable injury by codling moth on the check tree, but dusting gave nearly complete control. In 1919 at Grand Rapids dusting controlled all chewing insects very satisfactorily.

Foliage Injury. The foliage on dusted trees has been in better physical condition in every experiment than where the trees were sprayed. In some cases there has been some development of scab on the foliage of dusted trees, but this has never been severe.

DRY LIME-SULPHURS AND B. T. S.

Scab Control. The work with Sherwin-Williams dry lime-sulphur at Grand Ledge gave no conclusive results, as there was so little scab on the check tree. At Grand Rapids in 1919 the work with Duchess gave definite results. Sherwin-Williams and Dow dry lime-sulphurs and B. T. S. all failed to give satisfactory control of scab. The strength at which these materials were used made little difference in the results.

They were compared with standard lime-sulphur solution, 1 to 40, which gave better results than any of the substitutes.

ARSENICALS

Calcium Arsenate. In 1918 calcium arsenate was used in three orchards including Stark, Baldwin, Ben Davis and Northern Spy. It was used with dilute lime-sulphur and without the addition of lime. It caused rather severe foliage injury on Ben Davis, considerable injury on Northern Spy and slight injury on Stark and Baldwin. Codling moth injury was quite severe on the check trees of Ben Davis and Stark but where calcium arsenate was used the control was very good.

In 1919 calcium arsenate was used on Stark. Lime was added to prevent burning. It caused less injury than when used without lime but the control of codling moth was not so good as in 1918.

Magnesium Arsenate. This material was used on Stark and the results were very unsatisfactory. Foliage injury was very severe and the insect control was not satisfactory.

Lead Arsenate. This material has given uniformly good results wherever used. There has been very little foliage injury and insect control has been satisfactory. Corona dry lead arsenate has been used in nearly all the experimental work reported in this bulletin. NuRex-form brand was also used in 1919 and it gave satisfactory results.

Table IX summarizes the results of the counts for each plot in the various experiments.

TABLE IX.—SUMMARY OF RESULTS OF DUSTING AND SPRAYING EXPERIMENTS WITH APPLES.

Year.	Variety and Location.	Treatment.	Count Tree Number.	Total No. Apples.	Sound. Per cent.	Scab. Per cent.	Codling. Per cent.	Other Insects, Per cent.
1918	Baldwin at Morrice	Dusted	3	12115	98.1	0.7	0	1.0
		L-S and Cal. Ars	3	9462	95.2	0.9	0	3.8
		L-S and Ld. Ars	3	13354	95.0	1.1	0	3.8
		Check	1	2282	87.4	1.1	3.8	7.5
	Stark at Morrice	Dusted	3	9885	97.5	1.9	0.01	0.6
		L-S and Cal. Ars	3	7819	95.1	2.5	0.07	2.2
		L-S and Ld. Ars	3	7461	92.8	5.3	0.2	1.6
		Check	1	1229	52.3	16.4	27.5	5.4
	Baldwin at Belding	Dusted	4	6371	96.8	1.7	0.3	1.1
		Sprayed	4	5252	90.6	8.3	0	1.0
		Check	1	1324	62.0	36.0	0.5	1.3
	Spy at Muir	Dusted	2	2104	95.3	1.8	0.2	0.1
		L-S and Cal. Ars	2	2562	96.0	1.2	0	0.1
		L-S and Ld. Ars	2	3656	94.6	0.7	0.02	0.05
		Check	1	540	88.3	5.9	0	0.1
	Baldwin at Grand Ledge	L-S	2	4496	93.5	1.0	0.6	4.7
		S-W Dry L-S, 3 in 50	2	5089	93.4	2.0	0.6	3.8
		S-W Dry L-S, 5½ in 50	2	4272	95.0	1.0	0.6	3.0
		Check	1	2116	68.7	7.2	15.9	8.0
	Ben Davis at Grand Ledge	L-S and Cal. Ars	2	4567	96.1	1.1	0.8	1.8
		L-S. and Ld. Ars	2	4165	92.1	4.9	1.8	1.0
		Check	1	2060	38.1	13.4	46.8	3.3
1919	Duchess at Grand Rapids	Dusted	3	6185	86.9	12.6	0	0.3
		L-S	3	5322	84.2	15.1	0.07	0.4
		S-W Dry L-S, 3 in 50	2	2234	66.9	31.5	0.09	1.2
		S-W Dry L-S, 5½ in 50	2	1800	76.2	22.8	0.16	0.7
		Dow Dry L-S, 3 in 50	2	6696	61.0	37.9	0.09	0.9
		Dow Dry L-S, 50½ in 5	2	3919	63.8	35.3	0.10	0.6
		B. T. S., 7 in 50	2	2726	73.6	25.7	0	0.5
		Check	1	1153	21.5	62.3	9.9	27.6
	Stark at Grand Rapids	Corona Ld. Ars	2	6441	97.3	....	2.0	0.6
		NuRexform Ld. Ars	2	7295	97.5	....	2.0	0.3
		Corona Cal. Ars	2	5866	93.8	....	5.4	0.6
		Dow Mag. Ars	2	4215	86.5	....	11.6	1.8
		Check	1	2284	15.5	....	81.1	3.4

Key to abbreviations:
- L-S—Dilute lime-sulphur.
- S-W. Dry L-S—Sherwin-Williams Dry lime-sulphur.
- Dow Dry L-S—Dow Dry lime-sulphur.
- B. T. S.—B. T. S.
- Ld. Ars.—Lead arsenate.
- Cal. Ars.—Calcium arsenate.
- Mag. Ars.—Magnesium arsenate.

EXPERIMENTS WITH CHERRIES AND PLUMS

The work with cherries and plums has consisted of comparisons of the dusting and spraying methods of application and testing calcium and magnesium arsenates in comparison with lead arsenate.

EXPERIMENTS IN 1918

CALCIUM ARSENATE ON CHERRIES AND PLUMS

Blocks of Moore's Arctic plum and Early Richmond cherry on the Horticultural grounds at East Lansing were used for making a comparison of calcium arsenate with lead arsenate. The effect on the foliage was the main point of consideration.

Materials. The materials were used as follows:

1st. Calcium arsenate (dry), 1 lb. in 50 gal. No lime.
2nd. Lead arsenate (dry), 1¼ lb. in 50 gal.

They were used in combination with lime-sulphur solution, diluted at the rate of 1 to 40. All spraying was done with a spray gun and with high pressure. Each material was used on a plot of from seven to nine trees of each kind of fruit. Check plots of equal size of each kind of fruit were left unsprayed.

Applications. Three applications were made on the plums and two on the cherries. The first one was not made on the cherries. They were as follows:

1st. Just before blossoms opened.
2nd. Soon after the petals had fallen.
3rd. About two weeks after second.

RESULTS

The foliage of all trees was in excellent condition throughout the season. There was no injury that could be traced to spraying material.

DUSTING JAPANESE PLUMS

A planting of mixed varieties of plums on the College grounds at East Lansing was dusted in 1918. There were several species and several varieties of each species, including European, Japanese and native species. Since Japanese varieties are very subject to injury by several spraying materials, they were dusted to determine if such treatment would have any ill effects on the foliage. No check plot was left untreated nor was any other material used.

Material. A 90-10 mixture of sulphur and lead arsenate and pure sulphur were used.

Applications. Four applications were made as follows:

1st. Just before blossoms opened.
2nd. Just after the petals had fallen.
3rd. Two weeks after second.
4th. About one month before fruit was ripe.

The 90-10 mixture was used for the first three applications and sulphur only for the fourth.

RESULTS

The dusting materials caused no injury at any time on the Japanese varieties. The trees of the native and European varieties were also free from injury.

EXPERIMENTS IN 1919

A COMPARATIVE TEST OF ARSENICALS ON PLUMS

An orchard of plums on the College grounds at East Lansing, which contains blocks of Lombard, Shropshire Damson, and Moore's Arctic, was used for a comparative test of several arsenates. There were five rows of trees in this experiment and each row constituted a plot and contained trees of each of the varieties. A different arsenate was used on each row. Check trees of each variety were left unsprayed.

Materials. The arsenates used are listed below:

1st. Corona dry lead arsenate, 1¼ lbs. in 50 gal.
2nd. Corona calcium arsenate, 1 lb. in 50 gal. (lime added).
3rd. Dow magnesium arsenate, 1¼ lbs. in 50 gal.
4th. NuRexform lead arsenate, 1¼ lbs. in 50 gal.
5th. Rex calcium arsenate, 1 lb. in 50 gal. (lime added).

They were all used in combination with lime-sulphur diluted at the rate of 1 to 40.

Applications. Three applications were made as follows:

1st. Just before the blossoms opened.
2nd. Soon after the petals had fallen.
3rd. Two weeks after second.

All spraying was done with a spray gun.

RESULTS.

There was considerable foliage injury in all plots especially after the third application, but most of this was lime-sulphur injury as the temperature was quite high at that time. There was some injury which probably was arsenical injury but it was not severe and was not confined to any one plot. The foliage of the unsprayed trees was in excellent condition. Lombard seemed more susceptible to injury by spraying materials than the other varieties.

DUSTING AND SPRAYING CHERRIES AND PLUMS AT GRAND RAPIDS

On the farm of Mr. J. C. Maynard, near Grand Rapids, comparative tests were made with sulphur dust, lime-sulphur solution and bordeaux on Lombard plums and Montmorency cherries. Rather large plots were treated with each of the materials. No details of the experiment will be given as there was no development of insect or fungus trouble on the check trees of either fruit.

The trees in the *bordeaux* plot of each kind of fruit showed severe foliage injury. It was of the yellow leaf type and caused heavy defoliation. This was probably due to peculiar weather conditions which were very favorable to the development of such injury. There was a little *lime-sulphur* injury on both cherries and plums after one of the applications made during hot weather. The foliage of all *dusted* trees was in excellent condition.

DUSTING CHERRIES TO CONTROL SHOT-HOLE FUNGUS AT EAST LANSING

A block of eighty trees of Montmorency and English Morello on the College grounds at East Lansing was used for a comparative test of the dusting and spraying methods for the control of shot-hole fungus or leaf blight.* The trees are ten years old.

Materials. The orchard was divided into two plots so that each plot contained trees of both varieties. The arrangement of the trees and plots is shown in Chart VII. The materials were used as follows:

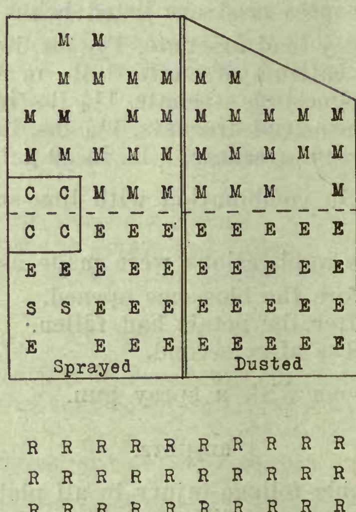


CHART VII. Diagram showing arrangement of trees and plots in cherry orchard at East Lansing. E, English Morello; M, Montmorency; C, check; S, small tree; R, raspberries.

Plot 1. Dusted. 90-10 mixture except for the last application when sulphur alone was used.
Plot 2. Lime-sulphur, 1 to 40. Lead arsenate was used when necessary.
Plot 3. Check. Untreated.

*Shot-hole fungus is caused by *Coccomyces hiemalis* Higgins. It is also known as leaf-blight, leaf-spot and yellow leaf.

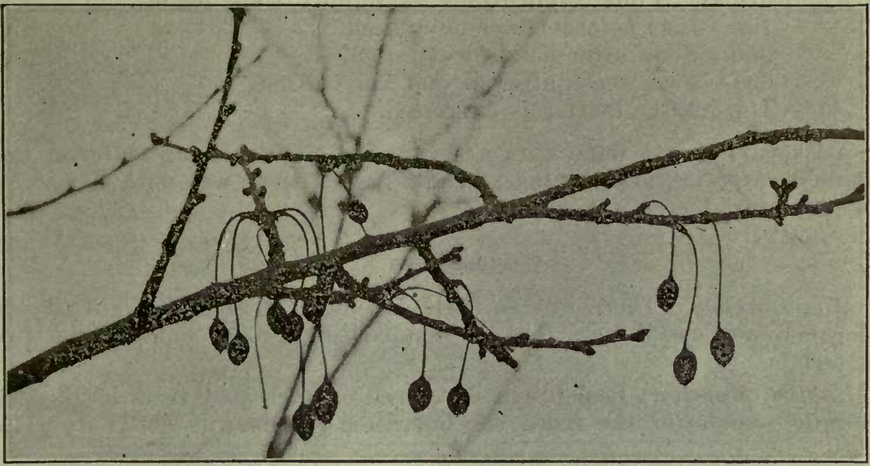


FIG. 10. CONIOTHYRIUM ON SOUR CHERRY. The cherries hang onto the trees after the leaves have fallen. This is a close view of several clusters of diseased cherries. Variety is English Morello. Photo. Nov. 20, 1919.

FIG. 11. CONIOTHYRIUM ON SOUR CHERRY. This shows the large number of cherries affected by this disease.

Applications. Four applications as follows were made:

1st. Just before blossoms opened.
2nd. Soon after petals had fallen.
3rd. Two weeks after second application.
4th. After fruit was harvested.

All spraying was done with a spray gun. The dusting material was applied early in the morning when the trees were wet with dew. An Ideal power duster was used.

RESULTS

Montmorency. There was so little development of leaf blight on the Montmorency check trees that no comparison can be made of the two materials.

English Morello. Leaf blight developed on the *check* trees of English Morello soon after the fruit was harvested. This was about July 15.

FIG. 12. CANE BLIGHT ON BLACK RASPBERRIES. This disease is caused by *Coniothyrium Fuckelii.* It frequently causes the fruiting canes to die before the fruit is mature.

It developed steadily until by September 1 the trees were practically defoliated.

On *dusted* trees the disease was evident early in August and by the middle of September many of the trees were badly defoliated.

Sprayed trees showed no evidence of leaf-blight until late in September and then the development was only very slight.

Coniothyrium on Cherries. When the fruit was being harvested it was noticed that many Morello cherries were drying up and hanging onto the trees. Some had nothing left but the pit covered with the dry cherry skin; some were partly dry and others were in just a slightly wrinkled condition. It was found that around the base of the stem of all affected fruits there was a cankered area which apparently had girdled the stem so that the sap supply was shut off. None of this trouble was found on Montmorency trees.

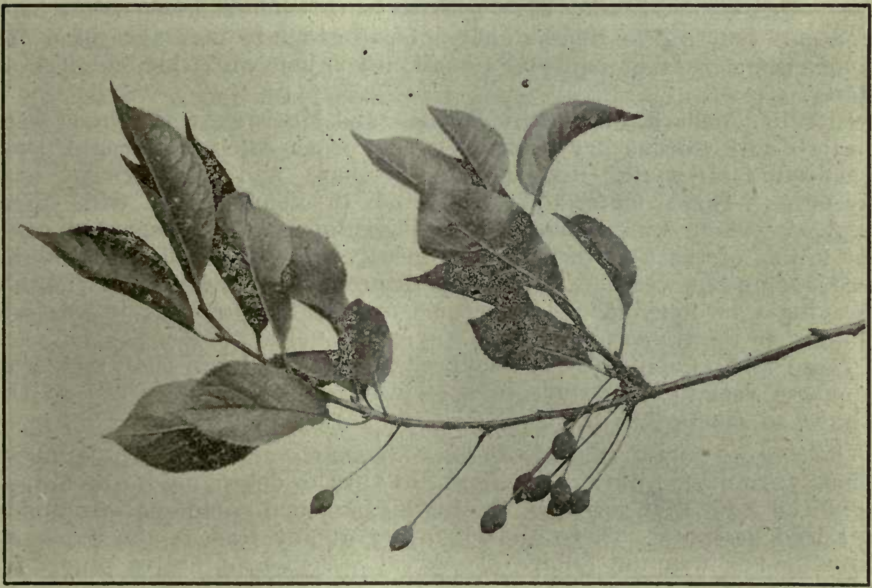


FIG. 13. CONIOTHYRIUM ON SOUR CHERRY. A small branch from an English Morello tree affected by Coniothyrium. Photo July 15, 1919.

All the affected cherries hung tightly to the tree throughout the summer and were still there in December.

The trouble was found to be caused by a species of Coniothyrium and might have come from a planting of black raspberries which stood just south of the cherry orchard.

There was considerable cane-blight in the berries which is caused by a fungus known as Coniothyrium Fuckelii.*

Control of Coniothyrium on Cherries. All trees in the *dusted* plot which bore fruit had cherries affected by this trouble. No affected

*The fungus on the cherries was identified by Ray Nelson of the Botanical Department.

cherries were found on trees *sprayed* with *lime-sulphur*. This indicates very strongly that dilute lime-sulphur will prevent the first or primary infection of this disease and that sulphur dust will not. No statement can be made at this time regarding the control of this disease after it has become established in the trees. Cane-blight is frequently found on black raspberries so it will be well not to plant them as an intercrop in cherry orchards or in close proximity to them.

SUMMARY OF RESULTS OF EXPERIMENTS WITH CHERRIES AND PLUMS

Foliage Injury by Arsenicals. In 1918 Moore's Arctic plums and Early Richmond cherries were sprayed with calcium arsenate in combination with dilute lime-sulphur. Lead arsenate was also used for comparison. Neither material caused any injury on either cherries or plums.

In 1919 Lombard, Shropshire Damson and Moore's Arctic plums were sprayed with Corona dry lead arsenate, Corona calcium arsenate, Dow magnesium arsenate, rex calsium arsenate and Nu Rexform lead arsenate. These materials were used in combination with lime-sulphur. There was considerable foliage injury on all sprayed trees but it was of the type of injury frequently found when lime-sulphur is used during hot weather. The temperature was high when part of this spraying was done. There was some arsenical injury but it was not confined to the trees sprayed with any one material.

These results indicate that sour cherries and plums (not including Japanese varieties) are not so susceptible to arsenical injury to the foliage as some other fruits.

Dusting Japanese Plums. Trees of several varieties of Japanese plums were dusted during the season of 1918 to determine if the foliage would be injured in any way by dusting material composed of sulphur and lead arsenate. There was no injury at any time to the Japanese varieties nor was the foliage of several varieties of native plums injured.

Dusting and Spraying Cherries at the College. An orchard of Montmorency and English Morello cherries was used for a comparative test of spraying with dilute lime-sulphur and dusting with sulphur dust for the control of shot-hole fungus. The work with Montmorency gave no conclusive results as no disease developed on the check trees. The work with Morello, however, gave definite results. Dilute lime-sulphur controlled shot-hole fungus satisfactorily. Dusting did not control it.

In the dusted plot a disease caused by Coniothyrium developed seriously but there was none of it on trees sprayed with dilute lime-sulphur.

EXPERIMENTS WITH PEACHES

The experimental work with peaches was all done in 1919. There were three separate experiments. One at Saugatuck for the control of leaf-curl by dusting, one at Grand Rapids comparing dilute and concentrated dusts with self boiled lime-sulphur and lead arsenate and the third at Grand Rapids as a test of magnesium arsenate in comparison with lead arsenate.

DUSTING TO CONTROL PEACH LEAF CURL

A test was made to determine if leaf curl can be controlled by the dusting method. This work was done in the orchard belonging to Mr. Jas. Boyce which is located about one mile from Lake Michigan and five miles north of Saugatuck. The variety was New Prolific. The trees were four years old.

Materials. About fifty trees were used for the experiment. They were divided into two plots and treated as follows:

Plot 1. Niagara Soluble Sulphur (for dusting).
Plot 2. 90-10 mixture of sulphur and lead arsenate.

Several trees were left untreated as checks. The lead arsenate in the 90-10 mixture was probably of no value except as a sticker. It would not have been used had any other mixture been available at that time.

Spraying. The main part of the orchard was sprayed by Mr. Boyce with Sherwin-Williams dry lime-sulphur. This material had been held over from 1918 and was used at double the strength recommended by the manufacturers because it apparently had deteriorated in quality.

Application. The dusting was done on March 7. The material was applied very liberally and from two directions. The spraying was done late in March. There were several days of quite warm weather soon after the dusting work was done and the buds undoubtedly swelled enough to allow an infection of leaf curl.

RESULTS.

The leaf-curl injury was very severe in this orchard as weather conditions were ideal for its development. The condition of the trees early in June in the several plots was as follows:

Check trees. The untreated trees were practically defoliated except for some new terminal growth.

Dusted. 90-10 mixture. Trees dusted with this mixture were in only slightly better condition than the check trees.

Dusted. Niagara Soluble Sulphur. The trees in this plot were in a slightly better condition than those dusted with the 90-10 mixture. The difference, however, was only very small.

Sprayed. The development of leaf-curl on the sprayed trees was severe, but the condition was much better than that of the dusted trees. The failure to control the disease on the sprayed trees was probably due to two factors: First, the warm weather before the spraying was done, and, second, the material used possibly was not effective. No definite tests have been made with dry lime-sulphur to control leaf-curl but since it has not given satisfactory control of apple scab it is doubtful if it would control leaf-curl.

MAGNESIUM ARSENATE ON PEACHES

A block of Early Michigan peaches on the Graham Experiment Station farm at Grand Rapids was used for testing magnesium arsenate. For comparison, one plot was sprayed with lead arsenate and another left unsprayed.

Materials. The block of trees was divided into four plots of from fifteen to twenty-five trees each and treated as follows:

Plot 1. Check. Unsprayed.
Plot 2. Corona dry lead arsenate. 1 lb. in 50 gal. and 3 lbs. hydrated lime added to each 50 gal.
Plot 3. Dow magnesium arsenate. 1 lb. in 50 gal. No lime added.
Plot 4. Dow magnesium arsenate. 1 lb. in 50 gal. and 3 lbs. lime added to each 50 gal.

The materials were used as listed above for the first application. For the second application Plots 2, 3 and 4 were all sprayed with self-boiled lime-sulphur and the poisons were used in combination with it.

Applications. Two applications were made:—

1st. As the last of the "shucks" were falling.
2nd. Two weeks after the first.

The spraying was done under high pressure and with a spray gun.

RESULTS

Check plot. The foliage of the trees in this plot was in excellent condition throughout the season.

Lead arsenate plot. The foliage of all trees in this plot was in very good condition. There was practically no injury; only an occasional small spot could be found. There was no loss of leaves from these trees. The condition was the same after both applications.

Magnesium arsenate. No lime added. Within two or three days after the first application the foliage began dropping. Practically every leaf showed injury and defoliation was very severe. Many small limbs were entirely defoliated so that the limb died and the fruid dried up.

Magnesium arsenate. Lime added. The effect upon the trees in this plot was much the same as where no lime was used but the injury was not so severe.

Magnesium arsenate with self-boiled lime-sulphur. The effect of this combination was about the same as when used with lime.

The combined effect of two applications on Plot 3 resulted in almost complete defoliation. On many trees, after the effects of the magnesium arsenate had passed, the only foliage left was the new growth that had developed after the spraying.

In Plot 4 the total injury was not so great and resulted in less permanent injury to the trees.

A COMPARISON OF DILUTE AND CONCENTRATED DUST MIXTURES WITH SELF-BOILED LIME-SULPHUR

A block of Crosby peaches on the Graham Experiment Station Farm at Grand Rapids was used for this experiment.

Materials. The block of trees was divided into four plots and treated as follows:

Plot 1. Check; untreated.
Plot 2. Self-boiled lime-sulphur. Lead arsenate added when necessary. Lead arsenate with lime was used for the first application.
Plot 3. Dilute dust. 50-40-10 mixture for two applications and 50-50 mixture for the last.
Plot 4. Concentrated dust. 90-10 mixture for two applications and straight sulphur for the last.

Applications. Three applications were made.

1st. Just as the last of the "shucks" fell.
2nd. Two weeks after first.
3rd. July 30.

The dusting was done with a large power duster and the spraying with a spray gun.

RESULTS

Disease and Insect Control. There was no injury by insects or diseases on the check plots so no conclusions can be drawn regarding their control.

Foliage Injury. There was no foliage injury found at any time in any plot.

Injury to Fruit. There was an occasional peach which was injured by the dusting materials. This was very rare and occurred only when the outlet had been close to the tree and a heavy coating of dusting material was deposited on the fruit. The injury occurred then only when the fruit was exposed directly to the sun. An injured peach is shown in Fig. 14. This type of injury is of little consequence as it does not occur under normal conditions.

SUMMARY OF RESULTS OF EXPERIMENTS WITH PEACHES

Dusting to Control Leaf-Curl. Peach trees were dusted with Niagara Soluble Sulphur (for dusting) and 90-10 mixture of sulphur and lead arsenate. Neither of these materials controlled leaf-curl. The condition of dusted trees was only slightly better than of check trees. The check trees were practically defoliated.

Magnesium Arsenate on Peaches. Magnesium arsenate was used, both with and without lime and with self-boiled lime-sulphur. One plot was sprayed with lead arsenate and there was practically no foliage injury. Magnesium arsenate without lime caused very severe injury and defoliation. Where used with lime or self-boiled lime-sulphur the injury was severe but not so bad as where used alone.

FIG. 14. SULPHUR INJURY ON PEACH. Such injury is occasionally found on dusted trees. It occurs only when a heavy coating of sulphur is deposited on fruit exposed directly to the sun. The skin turns black and cracks open if the injury is severe.

EXPERIMENTS WITH CURRANTS

DUSTING AND SPRAYING EXPERIMENTS WITH CURRANTS

The planting of currants on the Horticultural grounds at East Lansing was used for a test of several fungicides and insecticides. There were two sections of this experiment. One was a comparison of dilute lime-sulphur, bordeaux and sulphur dusts for the control of anthracnose. Anthracnose is caused by a fungus known as Pseudopeziza Ribis. It usually occurs as a leaf-spot. Another leaf-spot known as Septoria leaf-spot is sometimes found and can be controlled by the treatment recommended for anthracnose. The other part of the work was a test of lead arsenate, calcium arsenate and magnesium arsenate, to determine if any of them would cause foliage injury.

This planting contains bushes of several varieties and the experimental plots were arranged so that all varieties would be included in each plot. The arrangement of the plots is shown in Chart VIII.

Materials. The treatment given each plot is shown here.

Plot 1. Dusted. 90-10 mixture and straight sulphur.

Plot 2. Sprayed. Bordeaux. 4-4-50. Lead arsenate was used when necessary.

Plot 3. Sprayed. Lime-sulphur, 1 to 40 and Corona dry lead arsenate, 1 lb. in 50 gal. This plot was included in both sections of the work.

Plot 4. Sprayed. Lime-sulphur, 1 to 40, and Dow magnesium arsenate, 1 lb. in 50 gal.

Plot 5. Check. Unsprayed.

Plot 6. Sprayed. Lime-sulphur, 1 to 40 and Corona calcium arsenate, ¾ lb. in 50 gal., plus 3 lbs. hydrated lime.

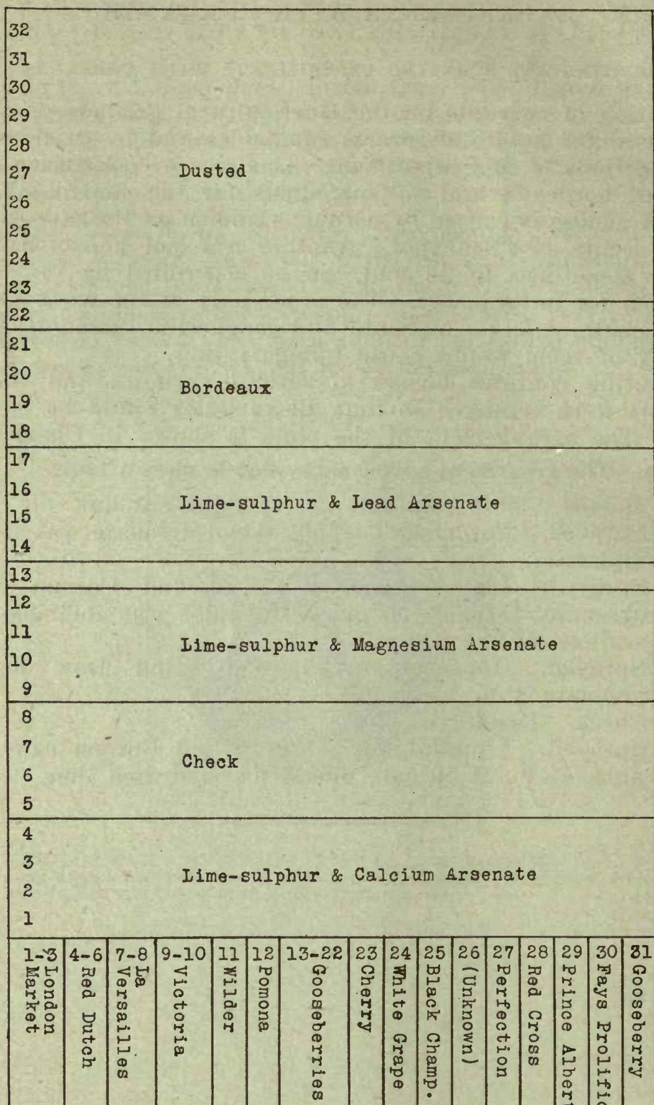


CHART VIII. Diagram showing arrangement of varieties and plots in currant plantation at East Lansing. There are 31 rows with varieties as indicated. Each row has 32 plants. The experimental plots were across the rows so that all varieties were included in each plot.

Applications. Dusting or spraying was done at five different periods as follows:

1st. Just as the leaf buds were opening.
2nd. As the fruit was forming.
3rd. Ten days after second application.
4th. Two weeks after third application.
5th. Soon after fruit was harvested.

The dusted plot only was treated at the fourth application. The fruit was so nearly ripe at that time that any spraying material would have spotted the fruit badly.

No arsenical was used for the third, fourth and fifth applications on the sprayed plots. For the fourth and fifth applications straight sulphur was used on the dusted plot.

RESULTS

Resistance to Disease. There was a great difference in the resistance of the different varieties to anthracnose. A partial list follows. This is based upon the time and severity of disease development on check plants.

Prince Albert—Very resistant.
London Market—Resistant.
Wilder—Susceptible.
Perfection—Susceptible.
Fay's Prolific—Susceptible.
La Versailes—Susceptible.
Cherry—Susceptible.
Red Cross—Susceptible.
Red Dutch—Very susceptible.

Prince Albert was practically free from disease throughout the season. London Market was not so resistant as Prince Albert. It held its foliage quite well until about September 1st, but lost considerable foliage after that time.

Wilder, Perfection, Fay's Prolific, LaVersailles, Cherry and Red Cross were quite susceptible to anthracnose and untreated plants lost their foliage quite early.

Red Dutch was very susceptible and untreated plants were entirely defoliated early in July.

Foliage Injury. The foliage of all plants sprayed with *bordeaux* was in excellent condition throughout the season. There was no physical injury and the leaves were vigorous and dark green in color.

The foliage of *dusted plants* was severely injured by the sulphur. Many plants lost much foliage because of this injury. The remaining leaves were light green in color and not so vigorous as where bordeaux was used.

Dilute *lime-sulphur* produced the same condition as the dusting sulphur. Defoliation was severe and the color of the leaves was not good.

Injury of this nature probably would not be so severe during a cooler season. Sulphur injury usually occurs when the temperature is high. Conditions in a currant plantation are probably favorable to such injury as the plants are low and close together so that there is not much circulation of air.

Disease Control. *Bordeaux* gave almost complete control of anthracnose on all varieties. Early in the summer when the new growth was developing rapidly there were times when the new leaves were not covred with spraying material. At such times anthracnose developed slightly on the terminal growth but was checked as soon as the next application was made.

The results with *lime-sulphur* and *sulphur dust* were similar. On resistant varieties there was little development of anthracnose but control was not so complete as with bordeaux. On the more susceptible varieties anthracnose caused considerable defoliation. The amount of injury varied with the resistance of the variety. Red Dutch plants in the sulphur plots were nearly defoliated by August 15. This was caused partly by sulphur injury and partly by anthracnose.

Results with Arsenicals. There was no foliage injury which was traceable to either *lead arsenate, calcium arsenate* or *magnesium arsenate.* There was foliage injury in all these plots but it was caused by lime-sulphur and developed some time after the last spray of arsenicals had been applied.

FIG. 15. PRINCE ALBERT CURRANT. A typical plant from the check plot. Very resistant to anthracnose. Photo. Sept. 10, 1919.

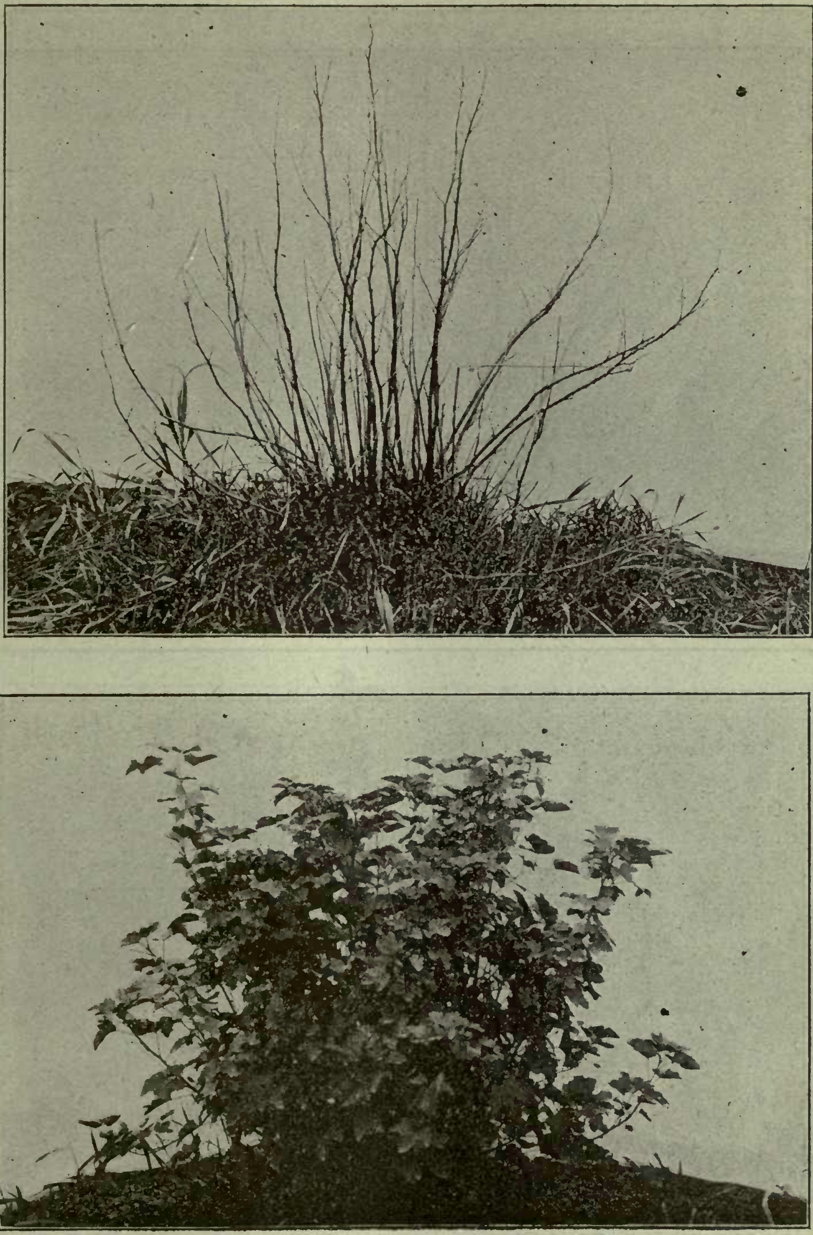


FIG. 16. RED DUTCH CURRANT.
(Above) A typical plant from the check plot. This variety is very susceptible to anthracnose. Plants in the check plot were defoliated early in July. Photo. Sept. 10, 1919.
(Below) A typical plant from the boardeaux plot. Bordeaux gave excellent control of anthracnose and caused no foliage injury. Photo. Sept. 10, 1919.

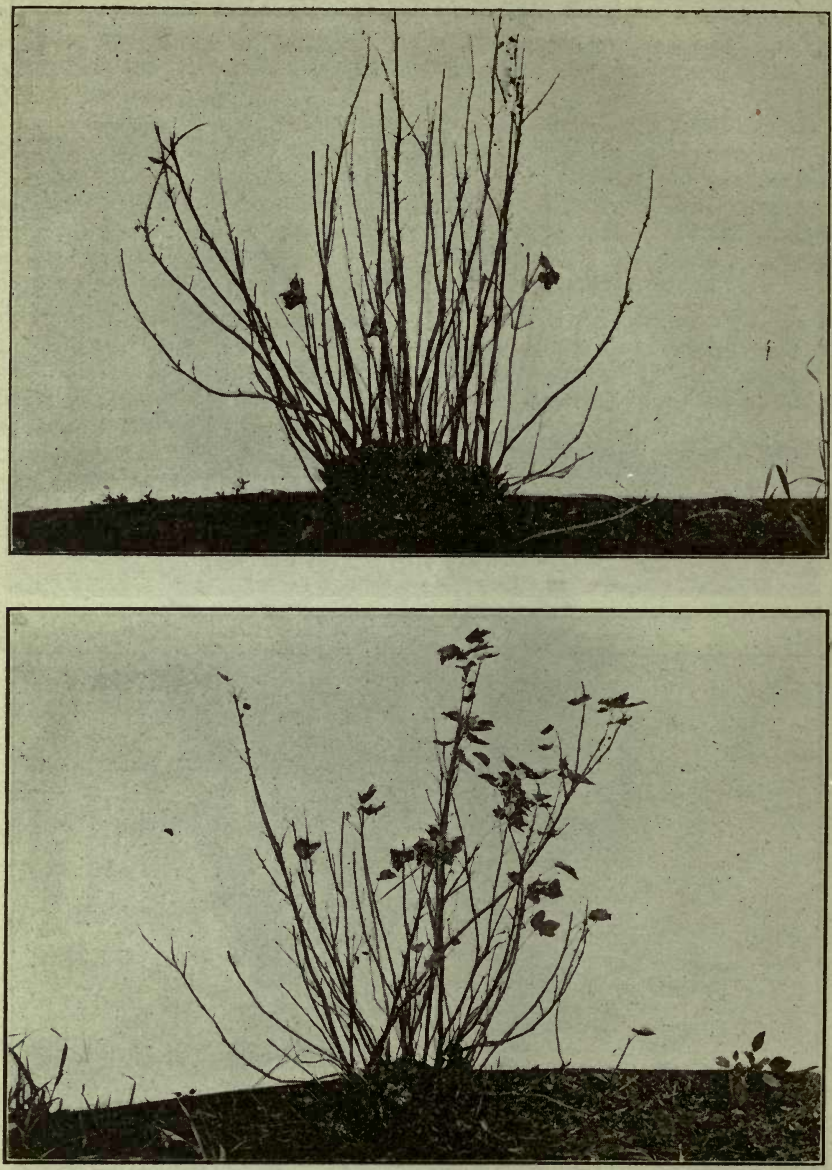


FIG. 17. RED DUTCH CURRANT.
(Above) A typical plant from the lime-sulphur plot.
(Below) A typical plant from the dusted plot.
Neither of these materials gave satisfactory control of anthracnose and both caused severe defoliation. Photos. Sept. 10, 1919.

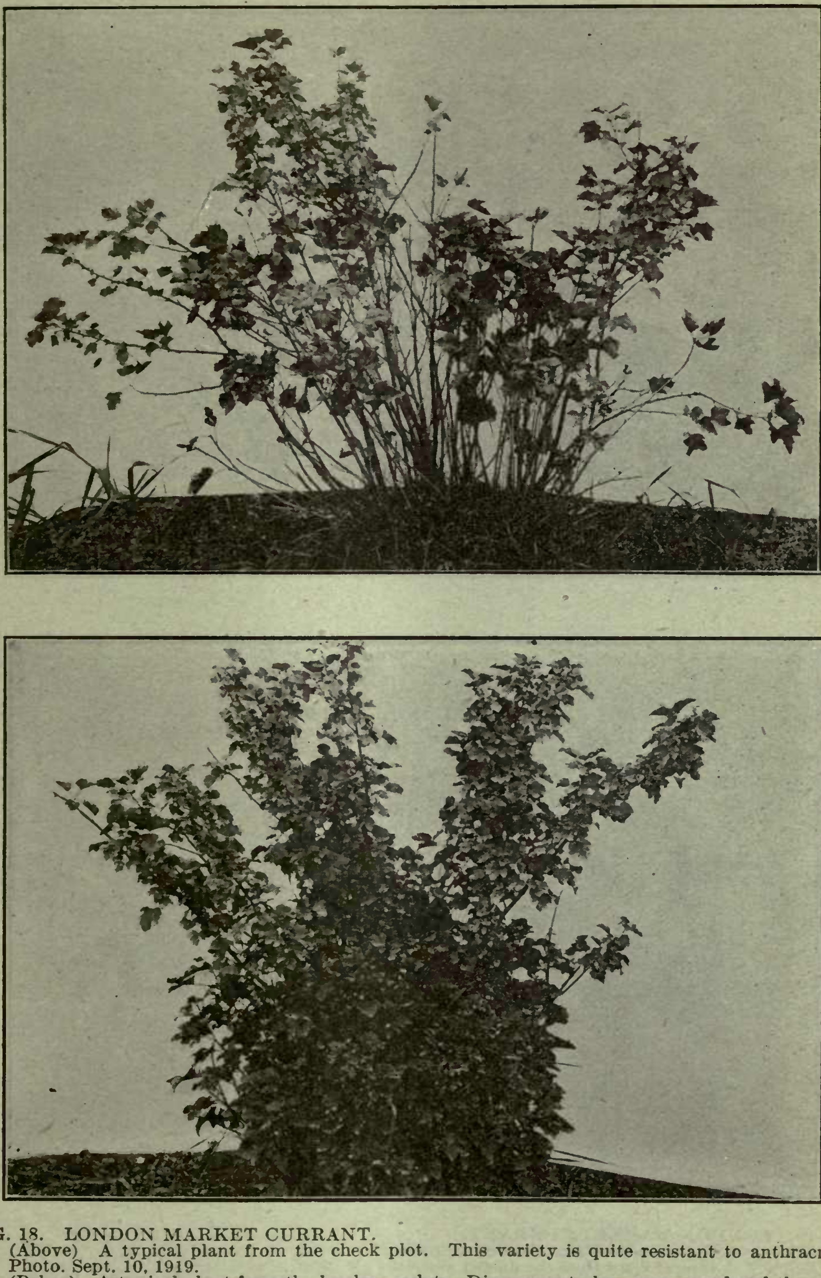


FIG. 18. LONDON MARKET CURRANT.
(Above) A typical plant from the check plot. This variety is quite resistant to anthracnose. Photo. Sept. 10, 1919.
(Below) A typical plant from the bordeaux plot. Disease control was very good and there was no foliage injury. Photo. Sept. 10, 1919.

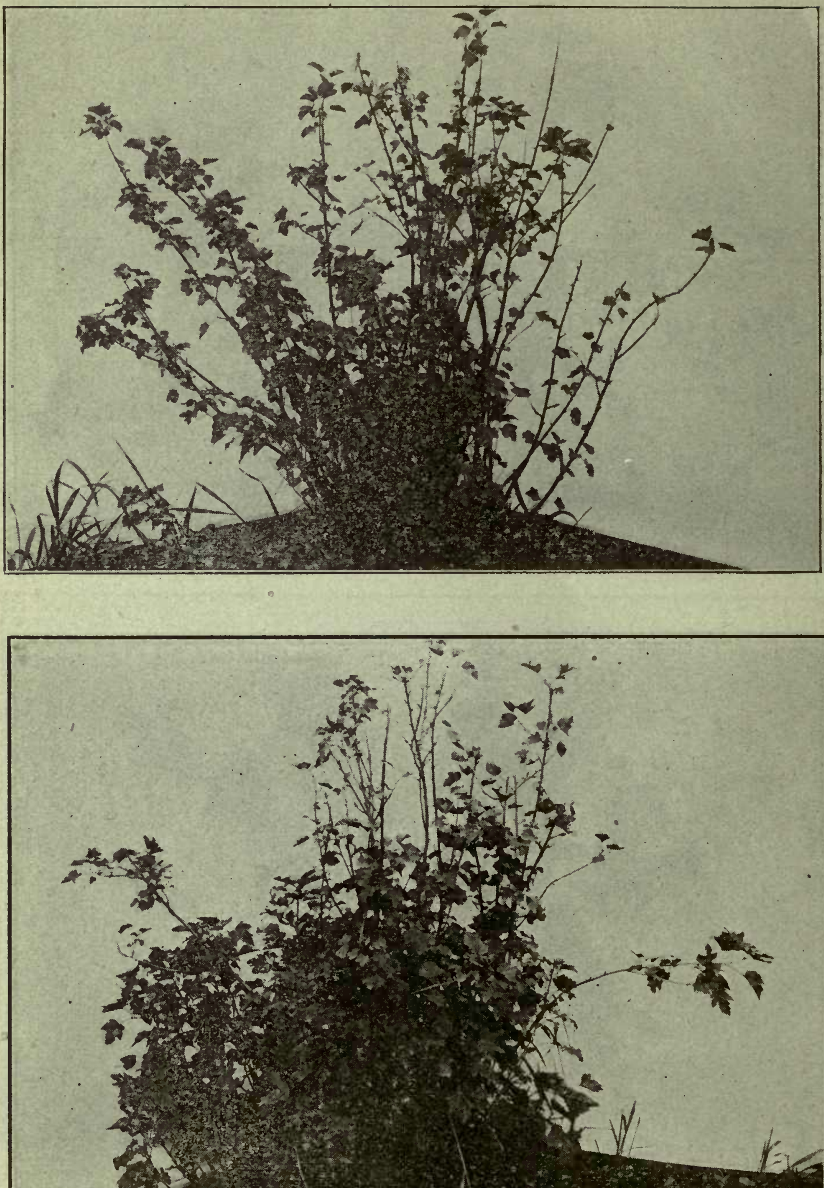


FIG. 19. LONDON MARKET CURRANT.
(Above) A typical plant from the lime-sulphur plot.
(Below) A typical plant from the dusted plot.
The results were about the same with both materials. Much of the defoliation was caused by sulphur injury. Photo. Sept. 10, 1919.

FIG. 20. PERFECTION CURRANT.
(Above) A plant from the check plot. This variety is susceptible to anthracnose but not so much so as Red Dutch. Photo. Sept, 10, 1919.
(Below) A plant sprayed with bordeaux. There was no foliage injury and disease control was excellent. Photo. Sept. 10, 1919.

SLMMARY OF RESULTS OF EXPERIMENTS WITH CURRANTS

Disease Resistance. Varieties of currants vary in their resistance to anthracnose. According to observations made in 1919, Prince Albert is very resistant and London Market is resistant. Wilder, Perfection, Fay's Prolific, La Versailles, Cherry and Red Cross may be classed as susceptible and Red Dutch as very susceptible.

Foliage Injury. The foliage of all plants sprayed with bordeaux was in excellent condition at all times. Sulphur dust and dilute lime-sulphur caused severe foliage injury.

Disease Control. Bordeaux gave excellent control of anthracnose on all varieties. Sulphur dust and dilute lime-sulphur did not give satisfactory control, especially with the more susceptible varieties.

Results with Arsenicals. Lead arsenate, calcium arsenate nor magnesium arsenate used in combination with dilute lime-sulphur caused any foliage injury.

Insect Control. As there was no insect injury on the check plants no comparison can be made of the different materials used.

EXPERIMENTS WITH POTATOES

DUSTING POTATOES TO CONTROL THE COLORADO POTATO BEETLE

In 1918 on the Horticultural grounds at East Lansing a comparison was made of the dusting and spraying methods of application of poison for the control of the Colorado potato beetle or "potato bugs" as they are commonly called. A small field of about fifty rows was used for this work.

Materials. The field was divided into two plots of about equal size. They were treated with materials as follows:

Plot 1. Dusted. An 85-15 mixture of calcium arsenate and talc was used. The talc was simply a filler or diluent. This mixture was very fine, smooth and easy-flowing.

Plot 2. Sprayed. Calcium arsenate at the rate of 1½ lbs. in 50 gallons of water.

Application. The dusting was done with a power orchard duster and with the regular orchard outlet which is simply a galvanized iron pipe four inches in diameter. Four rows were dusted at each trip through the field. The outlet was held rather close to the ground and swung from side to side. The plants were covered satisfactorily in this way.

The spraying was done with an attachment with two nozzles for each row.

RESULTS

As soon as the dusting and spraying were finished a number of plants in each plot were marked for observation. Plants were selected for this purpose that had a considerable number of adult beetles or larvae on them. There were, however, only a few adult beetles found at that time, most of the insects being in the larval form.

Both methods of application were entirely successful. Within two hours after the application of the dusting material, the larvae were showing effects of the poison. No live larvae could be found the next morning (eighteen hours after application) on either plot.

GENERAL CONCLUSIONS

DUSTING

Apples. During the last three years* apple scab and chewing insects have been controlled satisfactorily by the use of dusting materials. The results have been equal to or better than where dilute lime-sulphur and lead arsenate were used.

No assurance is given that dusting will give satisfactory results in seasons when weather conditions are more unfavorable than in 1917, 1918 and 1919. Weather conditions during 1917 were very favorable to scab development but conditions were not so bad as in 1915 and 1916. In many orchards in 1918 there was very little scab development even on untreated trees. In 1919 conditions were favorable for scab development early in the season and unfavorable later.

The dusting method of application, however, is recommended at this time as a supplement to spraying. Dusting is not a complete substitute for spraying as no dusting material has been developed which can be recommended for the complete control of scale insects. No recommendation can be made covering aphis control because of the lack of injury on check trees.

Cherries. Sulphur dust failed to control shot-hole fungus on English Morello cherries. It also failed to prevent the primary infection of Coniothyrium which developed seriously on trees of this variety. Dilute lime-sulphur controlled shot-hole fungus and prevented any development of Coniothyrium.

Plums. Dusting mixtures composed of sulphur, lead arsenate and tobacco dust have caused no injury to plum foliage (Japanese varieties included).

Peaches. Dusting is not recommended for the control of leaf-curl. No definite recommendation can be made regarding summer dusting of peaches except that dusting materials have caused no foliage injury. The indications, however, are that dusting will give satisfactory control of peach scab, brown rot and curculio. Favorable results have been reported from other states.**

Currants. Sulphur dust and dilute lime-sulphur are not recommended for use on currants to control anthracnose because of foliage injury during hot weather and their failure to control the disease satisfactorily on all varieties. Bordeaux gave almost complete control of anthranose and caused no foliage injury. It is recommended for use on currants where the leaf-spot diseases cause serious injury. It should be used according to the schedule followed in the experiments reported in this bulletin.

*See Special Bulletin 87 for results of work in 1917.
**Bul. 167, West Virginia Agricultural Experiment Station and Circular 21, Georgia State Board of Entomology.

Potatoes. Dusting potatoes with calcium arsenate for the control of the Colorado potato beetle has given excellent results. Such work can be done with an orchard duster and without any special outlet for distributing the material to each row. If there is much work of this kind to be done, it would probably be better to secure a special attachment.

DRY LIME-SULPHURS AND B. T. S.

The dry lime-sulphurs and B. T. S. have not given satisfactory control of apple scab so they cannot be recommended for the summer spraying of apples as a substitute for lime-sulphur solution.

No experiments have been conducted with this material for the control of San Jose scale as it has not been possible to find enough live scale during 1918 and 1919 for reliable tests of this kind.

ARSENICALS

Lead arsenate is recommended for general use on all kinds of fruits. It has given uniformly better results than any other arsenate.

Calcium arsenate has given excellent results when used on potatoes and other similar crops, but has not always given satisfactory results when used on fruit trees.

Magnesium arsenate has caused severe foliage injury on peaches and apples and has failed to give satisfactory control of codling moth. This material probably will not give such unsatisfactory results in every instance but since there is danger of injury from its use it is not recommended at this time.*

*This material at this time is manufactured in a form which is supposed to be non-injurious to foliage. It cannot, however, be recommended without further tests.

SUGGESTIONS

Dusting may be done when the foliage is either wet or dry. Some growers prefer to dust at night as atmospheric conditions are usually more favorable. Dusting cannot usually be done satisfactorily and economically when there is much wind.

Dusting material should be applied to the trees from two directions for each application. A satisfactory way is to dust with the wind on two different days when the wind is in different directions. When dusting at night the same method is desirable as there is usually a definite air current which causes the dusting material to drift in one direction. Under ordinary conditions it is not necessary to stop at each tree.

The cost per tree for material is much higher for dusting than for spraying, but the cost of application is less for dusting. Dusting can be done very much more rapidly than spraying and because of this it is possible to cover the orchard quickly at critical times and to make extra applications when desirable.

Dilute dusting mixtures are not recommended at this time. More experimental work is necessary before any recommendation can be made.

Ordinary commercial sulphur is not suitable for dusting purposes. Only special dusting sulphur should be used.

Some foliage injury has been caused where spray guns have been used. This can be avoided if proper care is taken. This injury is usually on the lower limbs and where the gun was held close to the tree. Use the driving spray as little as possible, avoid drenching the trees and always use the fine spray when covering parts of the tree close to the operator.

Dry in Montana 9

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Trees and Shrubs on the Farm

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The people who have but recently made their homes in Montana, especially those on the dry farms of the State, will hardly fail to appreciate the value of trees when looked at purely from the standpoint of pleasure. Some who have lived on Montana farms longer may have become accustomed, in a way, to their surroundings, and the absence of trees no longer causes discontent. They have gradually come to believe that trees and shrubs can not be grown under existing conditions. And possibly there are a few who do not appreciate trees and shrubs. However, as a protection from the glaring sun and drying winds in summer and severe cold in winter, trees and shrubs properly planted and cared for can not but add to the comfort of the home and, to most of us, contribute no little amount of pleasure. But comfort and pleasure are not the only returns the planting of trees and shrubs may bring to those upon the farm.

Note.—The information contained in this circular is presented with the non-irrigated farm uppermost in our mind, for it is on these farms that difficulties are most often experienced in growing trees and shrubs. Many of the suggestions are nevertheless applicable to the irrigated farm and in the later pages will be found some special advice for those who use irrigation water. We feel that the circular will answer well the many demands for information which come from every part of Montana.

There are those who claim that the planting of trees in large numbers upon the plains would greatly modify the climate of these regions, that the rainfall would be increased, and that drying winds would be less frequent. And trees are sometimes planted, even on the dry farm, with a view to financial returns. The wood lot or the shelter belt does, in some cases, furnish fuel for the home and posts for the fences.

Many farm homes have been improved by growing trees under conditions as trying as those found on the dry farms of Montana. It is surely worth a trial. When the matter is summed up, we find that the degree of success is measured largely by the proper selection of plants, proper selection and preparation of soil, and proper planting and care of the trees and shrubs.

SELECTING THE SITE

In many cases the location of the farm home is definitely fixed, the plan is already started and the problem is to complete it, but there is much to be gained in the proper selection of the site. Most of us have more or less positive ideas as to how the farm should be arranged for convenience. Some no doubt give it little thought. Most people prefer to have the house near the highway, and, keeping this one thought in mind, it should otherwise be about centrally located. While it is in some ways convenient to have the house at the cross-roads corner, it may cause a waste of time in going to and from work and in most cases it results in greater difficulty in planning and planting. While not always possible, it is under most conditions more desirable to have a south or east front. If one must have a windbreak to the north and west it is hard to front the house in these directions.

Do not make the mistake of plotting into fields all the tillable land on the farm and leaving the rest for the home grounds. It is impossible to grow trees, shrubs, and especially lawns upon poor soil. An attractive home lot will do more to increase the valuation of the farm than the best ten-acre field on it.

Occasionally there is a limited amount of irrigation water to be had. If possible, locate the home where this may be used on the garden, orchard, and lawn. It will yield greater returns here than on any other part of the farm.

PROTECTING THE HOME GROUNDS

One of the first points to be considered after the selection of the site for the home is that of proper protection of the grounds from your own and your neighbors' stock. Trees and shrubs and garden vegetables planted upon the dry farm can be expected to thrive only when given the best of care and protection. The trees and shrubs may need pruning and the orchard frequent cultivation, but cows and horses are poor pruners and hogs hardly follow approved dry farm practices in such cultivating as they may do.

The fence should be high enough and strong enough to turn all kinds of live stock, with the possible exception of chickens. It should extend around the entire grounds and should be set out far enough to prevent stock from reaching the plants in any way. As a rule the barnyard should be fenced off from the rest of the grounds, especially if stock are allowed any freedom at all about the barns. The one who tends the garden will usually realize the importance of having it fenced, especially as a protection against the chickens. Do not plant your home grounds and then build the fence; build the fence first.

PLANNING THE HOME GROUNDS

Some attention should be given to planning the yard for convenience. The house should be convenient to the orchard, the garden, and the barnyard; but it should be in a yard of its own, separate and distinct from the other portions of the grounds. It should be far enough from the proposed windbreak so the snows which drift inside the shelter will not be annoying about the house. The barns should be located with the same thought in mind. The orchard and the fruit garden should be located where they will be well protected by the windbreak; if they receive the drifting snows, so much the better. Snow is the best protection for small fruits, and, if caught and held within the orchard, supplies much-needed moisture. The entrance may be planned to serve equally well the house and the barn, or, better still, have a front entrance to serve the house and a side entrance to handle the larger part of the travel to the barn.

The house should be located far enough from the road to provide a good foreground—we can not make a good picture without a foreground—and the barn should be far enough from the house to allow for a good back yard and screen of shrubbery between the yard proper and the barnyard. Do not be afraid of setting aside ample land for the home grounds. Five acres, if well planned, is not too much and a smaller space does not allow for good arrangement.

PREPARATION OF LAND

The land to be planted to the home grounds should be well prepared and fallowed at least one year before any attempt is made to start trees and shrubs. The land should be deeply plowed and under most conditions fall plowing is preferable. During the following summer it should be well cultivated to keep down the weeds and conserve the moisture. If it is not practicable to keep the whole yard area cultivated, particular spots chosen for the location of clumps of trees or shrubs may be given a good mulch of straw or coarse stable manure. This will keep down the weed growth and conserve the moisture.

In plowing and working the land, avoid ridging it in places where rows of trees are to stand. On the contrary, the land should be so prepared that the rains will drain toward the newly planted trees. Be sure to cultivate well the area to be occupied by the trees and shrubs, the windbreak, and especially the yard, if an attempt is to be made to grow a lawn. If rows of trees are to be planted on the borders of the yard opposite the windbreak, it will be desirable to plow and summer-fallow strips of land at least ten feet wide here.

SELECTING AND BUYING THE PLANTS

Under such adverse conditions as prevail on our dry farms, it is only natural that one of the most frequent causes of failure is the improper selection of plants. The newcomer brings his ideas with him and attempts to work them out under conditions entirely different from those he is accustomed to. One can not hope for success in growing trees and shrubs unless he has made the proper selection of varieties to begin with. It is no doubt true that there is much yet to be learned about selection of plants for Montana conditions, but observations made in our own State and experiments carried on here and in other States under similar conditions have suggested some of the most promising kinds. Further experiments may lengthen this list.

Many are undecided as to where they should purchase stock. In the first place we may say that it should be bought of a well-established nursery, one that has developed some respect for its reputation. It is also safe to say that the trees should be bought as near home as possible. The local nursery is generally able to furnish kinds adapted to your conditions, and the stock from the nearby nursery has a better chance of reaching you in good condition than that from a distance. If you can not buy your plants near home, it is probably best to try some northern nursery, where varieties adapted to our conditions are more likely to be carried in stock. If the desired variety can not be purchased of the northern nurseryman, one need not hesitate to buy wherever it can be found.

One should buy always a good quality of plants, and under Montana conditions it is best to buy young plants. They are cheaper and more likely to grow. Forest tree seedlings one or two years old may be started more readily than older trees, and such plants are often used in starting windbreaks. Older plants are usually preferred for planting about the yard. A few trees about the house may be set with a little more care and given some water if necessary. Those listed by nurserymen as five to six feet high are a very satisfactory size. Shrubs listed as eighteen to twenty-four inches high are very good for yard planting.

Orders should be placed in early fall for stock to be delivered the following spring. As soon as the trees arrive they should be unpacked and heeled-in in some shady place, as on the north side of a building, or stored in a cool cellar. They should be kept cool to retard the growth of the buds and moist to prevent them from drying out. In heeling-in the trees, dig a trench and set the roots well down in the moist soil and tramp the earth well about them. If the soil is not quite damp, it is best to settle it about the roots with water. If the weather is dry and especially if the trees look rather dry when unpacked, it is best to bury them root and top in moist soil. If everything is in readiness when the trees arrive, they may be planted at once. Should they appear dry, it is best to soak them in fresh water from twelve to twenty-four hours before planting. Trees planted in a shriveled condition are seldom able to revive, while the same trees freshened in soil or water may make a successful growth.

SEASON TO PLANT

Under Montana conditions, trees and shrubs should be planted in early spring, as soon as the native vegetation starts. The young plant must start growth on the food material stored up in its roots, trunk, and branches. If the planting is delayed until the plants have leafed out, this leaf surface generally dries up and the food used in producing it is lost. With its supply of food diminished in this manner, the plant has its chances for surviving reduced proportionately.

HOW TO PLANT

Before setting the plants in the ground, trim off all broken ends of roots; and if any roots are exceptionally long, cut them back to six or eight inches in length. Handle the trees carefully to avoid drying the roots. A good way is to haul them to the field in a barrel with water enough to cover the roots. Take them from the barrel as they are to be planted.

To plant forest tree seedlings or small hedge plants, push the blade of the spade down into the ground and work it back and forth until the roots of the trees may be slipped down behind it. Remove the spade and tramp the soil well down about the roots. If a little water can be poured into the hole before the soil is pressed back about the roots, so much the better. In either case, after the tree is planted and the soil is well packed about the roots, see that the surface soil is loose enough to prevent rapid loss of moisture.

It will pay to plant specimen shade trees and shrubs with a little more care. Dig a good hole and spread the roots out well. In all cases set the plants three or four inches deeper than they stood in the nursery. The tops should be pruned after the trees and shrubs are set. Cut forest tree seedlings back to within a foot or even six inches of the ground. Prune shrubs the same way. On the larger trees remove about one-half of the top. Some of the limbs may be cut out entirely and others cut back one-third of their length. This pruning at planting time should not be neglected for it is very important. Most of the root system has been destroyed in digging and if the entire top is left the remaining root system can not support it and the plant will seldom survive the first summer.

Native plants can often be used to good advantage in beautifying the home. To grow plants from native seed is slow, inconvenient, and unsatisfactory, as well as unnecessary where there are plenty of native seedlings which can be used. Possibly, however, many failures have discouraged some in the use of native stock. If a few principles involved are carefully followed, many places now devoid of trees can be easily made more homelike and attractive. A little attention as to the time of planting, selection of trees, trimming tops and roots, preparation of land, digging holes, filling in dirt around trees, watering, and perhaps shading in the case of evergreens, will go a long way towards success in transplanting these native trees.

In transplanting deciduous trees two important points should be kept in mind. (1) Many native trees, growing unmolested from seed, tend to develop a tap-root system, or at least a coarse, straggling root system. In digging such trees it is difficult to get a root system that is anywhere nearly proportioned to the top, and the older the tree the more difficult is the problem. Large nursery-grown trees are handled more easily for the simple reason that they have been transplanted one or more times and have developed a compact and more fibrous root system. In planting these native trees, therefore, it is well to remember that small trees should be chosen and by selecting those that grow in good soil rather than on rocky hillsides we are pretty sure to get a root system that will stand transplanting better. (2) Native trees, especially when growing in thick clumps, protect each other. Such trees can not be expected to survive a sudden transition to open exposure on the prairies. Losses from this cause can be minimized by selecting specimens growing by themselves, or by first moving them to nursery rows where they can be grown close together for two or three years. They will thus be gradually adapted to exposed conditions and the survivors will be suited for planting in permanent positons. Of course where a great many trees are planted close together as in a windbreak they afford each other more or less protection.

Greater care is necessary in handling evergreens as they are in leaf all the time and will not stand neglect. The roots should not be exposed at all to the air. If it is not possible to dig trees with a ball of earth attached, the roots should be dipped in mud and wrapped to prevent drying. Small trees twelve to fifteen inches high should be selected and planted in small beds where they may be given partial shade. Satisfactory shade may be provided by a brush or lath screen placed twelve or eighteen inches above the tops of the trees. A good screen may be made by nailing laths on a frame of any convenient shape, leaving openings about an inch wide between the laths. The trees may be planted rather close together but not close enough to crowd in the next two years. After two years they may be moved to the nursery row where they should grow two or three years before they are moved to the permanent location. Even then it is a good plan to plant them rather closely for mutual protection or to plant them among deciduous trees, thinning out the latter as the evergreens grow. If planted thickly, some of the evergreens will need to be thinned out later. If handled as suggested for transplanting large trees, those thinned out can often be used in other places. Evergreens should be moved early in the spring just as the buds open. Patience is necessary but the reward is more than sufficient. Single trees twenty-four to thirty inches high may often be moved from the timber to the yard if carefully dug and planted, and shaded for two or three years with a lattice screen.

Details given elsewhere for setting out trees apply equally well here. Deciduous trees from the woods should be more severely top pruned when first set out than those from nurseries. Evergreens are usually not pruned when moved but it is well to watch for double leaders and cut one out.

MOVING LARGE TREES

Rather large trees, if they have been transplanted once while young, are often successfully moved. In such cases it is best to dig a trench around the tree in the fall. This trench should be three feet deep and several feet from the base of the tree. The ball of earth thus marked out can be partly severed from the earth beneath. The trench can be filled with straw or similar material and the ball of earth left to freeze. Before the ground thaws out the following spring the straw is removed and the tree with the frozen earth moved to its new location. The hole to receive the tree must be prepared in the fall and kept from freezing by filling with straw or coarse manure. It is a good plan to move just as much earth as possible with the tree. Evergreens up to six or eight feet in height may be moved in this manner. The ball of earth should have a diameter of at least two-thirds the height of the tree. Even trees moved in this way should be shaded for one or two summers.

CULTIVATION

During the first summer the windbreak, the rows of shade trees, and the hedges should receive good, clean cultivation. Individual plants or clumps that can not well be cultivated may be mulched with straw or coarse stable manure. The windbreak should be cultivated as long as it is possible to go between the trees.

It may be well to mulch the soil about young trees and shrubs for the first winter at least. If mice are inclined to be troublesome, the mulch should not extend up to the trunks of the trees. To prevent injury by mice, pile a cone of earth eight inches high about the base of the tree and then mulch outside of this.

PRUNING

The object of pruning is to keep trees and shrubs in a good state of health and vigor. To this end we try to assist rather than change their natural habits of growth. To become proficient one should learn (1) what to remove, (2) when to prune, and (3) how to make proper cuts.

What to remove from trees.—Diseased and dead parts should be removed. This is preferably done as soon as noticed, although most of such work may be done early in the spring, as noted later on. If two branches rub, one should generally be taken out, although cases may arise where it is desirable to head back one of them below the place where it rubs. On lawns where high-headed trees are desirable, trees should not be allowed to branch close to the ground. As the tree grows, the lower branches should be pruned off; at least they should not be allowed to grow very large. Where trees are exposed it is often desirable to allow small branches to grow rather low for a season or two as a protection to the trunk. The branches should be kept as small as possible by severe heading back, say to two or three buds, and they should be taken off before they get very large.

What to remove from shrubs and bushes.—Dead and diseased parts should be removed. Caragana, honeysuckles, Russian olive, and some others will stand rather severe heading back if it is desirable to keep them low. Sometimes it is necessary to thin out some of the wood when it gets too thick. Death of branches in the center of bushes or a spindling growth of these branches usually indicates that the bushes are too thick. In any case it is well to remember that moderate annual prunings are better than spasmodic severe prunings. The latter often means the removal of large limbs. This should be avoided as much as possible.

When to prune.—It is best to prune trees and shrubs early in the spring before growth starts. Shrubs which bloom very early in the spring are often pruned after the blooming season or in early summer. In our dry climate pruning in the fall or early winter is not a good practice. Dead wood of course is unsightly and may be removed at any time.

How to make proper cuts.—In heading back a branch, cut to a bud or to a lateral branch. When large branches are headed back to laterals, the latter take up much of the excess sap and prevent the formation of many water-sprouts. In cutting off side branches, cut them close to or flush with the surface of the branch from which they arise. Do not leave stubs. If cut properly the wound may be a little larger than when a stub is left, but it will heal more quickly.

It is generally advisable to paint wounds which are two inches or more in diameter. For this purpose a good grade of white lead paint is one of the best dressings. This paint should be thick and should not be applied in excess as it may run down over the bark and injure it.

THE WINDBREAK

The purpose of the windbreak is one of protection. It should protect the buildings and the fruit and vegetable gardens from sweeping winds. In winter it should stop the blowing snow and prevent it from piling up about the buildings. Such protection adds much to the comfort of the home, and without some such protection from drying winds it is almost useless to attempt to grow fruit upon the dry farm. In summer the windbreak checks the winds which rob the soils of the garden, orchard, and yard of their moisture. If it is to serve these purposes it must be dense enough and wide enough to stop the wind. To make it dense, it must be made up of trees of varying habits of growth. A grove of cottonwoods will not serve the purpose, as the lower limbs soon die off and allow the wind to rush through underneath. Nor will a grove of low-growing shrubs serve all the purposes of a windbreak. It must be a combination of the two. The width should be from fifty to one hundred feet, or even wider, depending upon the force of the winds.

In most sections of Montana east of the divide, the troublesome winds are largely from the north and west. This means that the home grounds must be protected at least on these two sides. The windbreak should be far enough from the buildings so the snow which collects inside will not be annoying. With a properly constructed break one hundred feet is probably a safe distance. The planting should be so arranged that the snow will collect among the trees as much as possible. To encourage this the smaller trees and shrubs should be planted to the windward and the others arranged in order of height with the taller ones inside. A desirable windbreak is made up of one row of Siberian pea tree on the north and west, one row of box elder next, then two rows of box elder and green ash mixed, and on the inside two rows of poplar or cottonwood. The drifting snows should pile up within this grove and greatly increase the moisture supply.

For making a windbreak the most promising trees are the Canadian poplar, native cottonwood, box elder, golden Russian willow, green ash, white elm, and Siberian pea tree. The Canadian poplar (*Populus balsamifera*) is one of the hardiest of the poplars. It is a rapid grower and lasts well. The common, narrow-leafed cottonwood found growing along the streams in the eastern part of the State may be used for the windbreak or the yard. It is probably not so rapid a grower as the Canadian poplar and does not last as well. It should not be used when the poplar can be secured. The box elder is also a native of the State and will thrive under most conditions. It is a tree of rather straggling habit, grows rapidly, and thrives well in the windbreak as a tree of intermediate growth. The golden Russian willow will succeed on good soil with a little more than the average rainfall. It makes a rapid, dense growth, may be trimmed low, and where the conditions are favorable it is an excellent tree for either the outside or the second row in the windbreak. The green ash is found growing along the streams of eastern Montana. With good care it may be induced to grow on the dry farm, especially when planted in groves. It is not so rapid a grower as the other trees mentioned, but it is a more permanent tree. For this reason it is well to alternate this tree in rows with the box elder and poplar, with the idea of removing the shorter-lived trees as they begin to crowd. The white elm thrives in some sections of Montana. Where the growing season is not too short and where the rainfall is a little above the average, the elm may work out well as a windbreak tree. It is long-lived and may be alternated in the rows with poplars as it grows quite slowly at first. The Siberian pea tree is one of the hardiest plants available for windbreak purposes. It is a small shrub, rarely growing over fifteen feet high. It makes a low, compact growth, and for that reason makes a first-class tree for the outer rows. It should be used in preference to the golden Russian willow where there is doubt as to the willow's being adapted to the conditions.

Of course, the evergreens are not so promising for the dry farm. Yet after they become established they resist drought and severe weather even better than some of the trees just mentioned, and they would surely make ideal windbreaks. It is possible that after a shade is once produced the bull pine may be started among the other trees. Attempts should be made to start only small specimens, those not over a foot high.

In arranging the windbreak the rows of trees should be placed from eight to ten feet apart, with the trees from four to eight feet apart in the rows. The trees in the outside rows may be planted as close as four feet, while permanent trees should stand eight feet apart. Where the ash and box elder are planted alternately, set the ash eight feet apart with a box elder between.

PLANNING AND PLANTING THE YARD

The planning of the yard should have the same careful consideration as does the planning of the home. Not only the convenience of the place but especially its attractiveness depends upon proper planning and planting. Considered from the standpoint of beauty alone, the yard may be planted by the same rules as those which the artist follows in painting a landscape. For after all the yard is to become a picture or a series of pictures, good or bad, depending upon the skill displayed in planning it. The artist would not paint a home scene with the house the foremost figure. He would not picture the entrance to the grounds as a straight lane terminating at the door of the barn, giving an unobstructed view of barnyard scenes, which are at best seldom attractive. Nor would he bound the yard by four lines of trees or shrubs, with no attempt to break the monotony by filling in the corners and planting here and there a clump of shrubs to break up the straight lines. So we should apply these rules to the planting of the home yard and make the house the central figure but not the foremost. The trees and shrubs should come to the foreground at the sides of the picture. Trees may be planted along the front border of the lawn, provided they are pruned up enough from below to give a good view of the yard from the highway. Hedges are more often used to screen unsightly portions of the home grounds, and unless one is ashamed of the front yard they should seldom be tolerated as a front-yard fence.

If the yard is small and there is no place for curved drives, the lane should at least make a slight curve after it passes the house; then a few trees and shrubs properly placed will screen the barnyard from the entrance to the grounds. If necessary to plant windbreaks made up of trees and shrubs planted in straight lines, the picture may be greatly improved by filling in the square corners with smaller shrubs and by planting clumps of shrubbery here and there inside the windbreak where it borders the yard proper. Small shrubs may be planted about the house to unite the house more or less with the lawn and to break up the straight lines. They should be used to fill in all retreating angles about the foundation of the house. Shrubs to be planted about the house should be selected and located with some care. In the first place they should be largely low-growing varieties. So long as it does not cover a window or crowd a doorway, a tall shrub like the lilac or honeysuckle may occasionally be used in some deep retreating angle about the house. Avoid planting trees and shrubs in places where they obstruct views from windows. If clumps of trees are planted about the yard, a few low shrubs planted near them will have the effect of finishing the picture.

A screen of shrubbery should separate the barnyard from the yard proper. This should be far enough from the house to give a roomy back yard which may serve as a children's playground, clothes-yard, etc.

A row of trees may border the lawn on the two sides opposite the windbreak. They should not be low-growing trees, however. Remember that at least from some points along the highway one should get a clear view of the lawn and of most of the house. If the yard is large, clumps of trees or even single trees may be scattered about the front and back yards. In planting trees and shrubs about the home it is in most cases desirable not to mix the planting too much. In other words, group together in one part of the yard a few lilacs, in another corner a few honeysuckles, etc. A clump of five lilacs with a background of other shrubs looks better than a clump made up of five different kinds of plants. Avoid crowding the yard full of trees and shrubs. Leave a goodly portion of open lawn. If the yard is small, one tree with a few shrubs about it will look better than a group of five trees with the additional shrubbery which would crowd the lawn.

The shrubs used in the yard must be selected from a rather limited list. The Russian olive may be pressed into service as a yard shrub. It makes a very good appearance when used in masses about the border, as a hedge, or as a screen. Two forms of the Siberian pea tree (*Caragana arborescens* and *Caragana frutescens*) are among the hardiest shrubs. The first mentioned grows to a height of fifteen feet, but it is useful as a shrub to be planted in masses or in hedges and screens. It takes several years to reach this height, and as it will stand severe pruning it may be kept down quite low. The other is a smaller shrub which grows into more graceful specimens. It is a useful shrub to plant about the house or about clumps of trees upon the lawn. Both forms produce rather showy yellow flowers.

The common lilac succeeds very well in trying locations. It may be used as a hedge plant in the screen or as specimen plants about the lawn. It grows into a graceful shrub or high hedge with little pruning. The Tartarian honeysuckle should thrive under dry farm conditions. It grows to a height of ten feet and forms a very graceful specimen plant with small but fragrant blossoms. It is a good plant for high hedges or screens or for filling in corners about the border of the yard. The buckthorn is another desirable shrub for hedges or screens. It stands pruning well and will make a stock-proof hedge. It should prove hardy under most conditions. Any of the taller-growing trees suggested for the windbreak may be used in the yard.

SPECIAL SUGGESTIONS FOR THE IRRIGATED FARM

Much of the information given in the foregoing pages will apply equally well to the irrigated or the non-irrigated farm. The choice of plants, time of planting, plan of planting, cultivation, pruning, etc., will be much the same in either case. However, a few suggestions particularly applicable to the growing of trees under irrigation may be helpful. Disappointments in tree culture come not alone to those who are denied the use of irrigation water. Many failures are experienced on irrigated farms and in many cases these failures may be attributed to wrong methods of irrigation. A simple statement of some of the principles underlying the use of water in growing trees seems desirable.

On the irrigated farm good soil preparation is important but not necessarily as long a process as on the non-irrigated farm. Summer fallowing is not necessary. Fall plowing is to be preferred. If plowed in the spring the land must be well worked down with a disk or packer for water can not be handled economically or satisfactorily on loose soil. It is seldom wise to attempt to start trees on newly broken sod land, even when water is available, unless the sod is exceptionally well cut up in the process of preparation.

Setting trees with water.—In setting trees with water, a hole should be dug large enough to accommodate the roots without crowding. If rows of trees are to be set and running water is available, a good plan is to plow out a furrow and dig the holes in the bottom of this. Place the tree in the hole, cover the roots well with earth, and turn water into the furrow to settle the soil covering the roots. Whether run in furrows or poured into individual holes, enough water should be used to thoroughly settle the soil about the roots. After the water has soaked away, the furrow and holes are filled with loose earth, which should not be packed. Always remember that it is wise to use plenty of water at the time the plants are set.

Irrigating trees and shrubs.—(1) Newly planted trees do not need frequent irrigation early in the season. The roots are not capable of taking up a great amount of moisture and too frequent watering retards growth by keeping the soil cool. Water the plants well at the time they are set and then withhold water until examination of the soil shows that the subsoil is really drying out. If the surface soil is kept well stirred about the plants, this first watering should last from three to five weeks, depending upon the nature of the soil and the weather. (2) The soil should be thoroughly soaked when the trees are watered. Frequent light irrigations encourage shallow rooting and really retard growth. Rows of trees are best watered by plowing a furrow on either side of the row. The first year these furrows should be from twelve to eighteen inches from the trunks of the trees. As the trees grow older the furrows may be moved a little farther away from the trees and increased in number. Remember that the spread of roots is somewhat greater than the spread of tops and that irrigation furrows should supply moisture to as much of the surface area as roots occupy. (3) Trees should not be irrigated late in the growing season. This encourages them to grow late in the fall and immature plants are more susceptible to winter-killing. Trees that are well ripened will stand much lower temperatures than those that keep on growing till late in the season. In most cases it is not wise to irrigate young trees later than the middle of August. If the soil holds water well, the first of August might be better. (4) Watering trees after the first frosts in the fall is sometimes a good plan, especially where the winters are very dry. A good supply of moisture in the soil during the winter lessens the danger of winter-killing.

SOME DESIRABLE SHRUBS TO USE

Barberry.—Unfortunately the common barberry and the purple-leaved variety are hosts for one stage of the stem rust of wheat. None should therefore be planted in the State and those that have been planted should be removed.

Barberry, Dwarf, (*Berberis Thunbergii*) is a dwarf barberry growing 2 to 4 feet high; green foliage; yellow flowers in late spring; red berries and foliage in fall. This should be protected during the winter as it is not fully hardy, especially when young. As the plants become older they endure winters better. This species does not harbor the wheat rust as does the common form.

Barberry, Common, (Berberis vulgaris) attains a height of 4 to 6 feet; foliage green; flowers in clusters borne in late spring; desirable also for its red fruit and foliage in the fall. **Harbors wheat rust.**

Barberry, Purple, (B. vulgaris, var. atropurpurea) is similar to the common green barberry in habits of growth but the foliage is a rich purple instead of green. **Harbors wheat rust.**

Buckthorn (*Rhamnus cathartica*) is a desirable hedge plant, 10 to 12 feet high; bears black berries in the fall.

Buckthorn, Sea, (*Hippophae rhamnoides*) grows about 8 feet high and resembles buffalo berry. The leaves are gray-green above and silver-green below. It bears yellow flowers in the summer, followed by orange-yellow berries in the fall, which hang on well into winter.

Buffalo Berry (*Shepherdia argentea*) grows 10 to 15 feet high. The leaves are narrow and silvery in appearance. It bears yellow flowers in early summer and red or yellow fruit in the fall. The berries are used in making jellies.

Chokeberry (*Sorbus arbutifolia*) belongs to the mountain ash group of trees and shrubs. It grows 6 to 12 feet high and is hardy at Bozeman.

Choke-Cherry (*Prunus Virginiana*) is native to most parts of Montana. It is easily transplanted and makes a desirable ornamental plant, especially in shrubbery groups.

Crab, Siberian, (*Pyrus baccata*) grows 15 to 20 feet high and bears fragrant flowers in the spring. The red fruits are very small, about like a good-sized pea. It is susceptible to blight and should not be planted in fruit-growing sections.

Currant, Golden or Flowering, (*Ribes aureum*) grows 6 to 8 feet high. It bears an abundance of bright yellow, fragrant flowers in the spring and black berries in the fall. It is desirable for shady locations.

Dogwoods (*Cornus*) are chiefly valued in shrubbery because of the green foliage during the summer and bright red colors of the twigs and branches during the winter. There are several species native to Montana that are ornamental and hardy under cultivation. Siberian dogwood (*C. alba* var. *Sibirica*) has proved hardy on the station grounds at Bozeman.

Hawthorn (*Crataegus Douglasi*).—Black haw is similar to scarlet thorn in height and color of flowers but the fruits are black. It is native to Montana.

Hawthorn (*C. coccinea*).—Scarlet thorn is a shrub growing 15 to 20 feet high, with apple-like blossoms in the spring, bright green foliage in summer, and red berries in the fall. It is hardy and will make a vigorous growth on rich, moist land.

Honeysuckle, Tartarian, (*Lonicera Tatarica*).—This shrub grows to a height of 10 feet. The flowers are pink, crimson, or white. The fruits are mostly red, though some bear yellow fruits. It is a native of Russia and Siberia and has proved hardy at this station.

Lilac, Purple, (*Syringa vulgaris* var. *purpurea*).—Though this plant is common in nearly all parts of the State it is none the less desirable for planting as its beautiful, fragrant flowers,dense foliage, readiness of growth, and variable habits make it well suited for shrubberies, ornamental hedges, or specimen plants.

Lilac, White, (*S. vulgaris* var. *alba*).—This variety should become more prominent as the white flowers make a pleasing contrast with the purple lilac. It is as hardy as the latter and blossoms profusely.

Pea Tree (*Caragana frutescens*) grows 5 to 6 feet high and bears yellow flowers in late spring or early summer. It is hardy at Bozeman.

Pea Tree, Siberian, (*C. arborescens*) grows 12 to 20 feet high and is entirely hardy. The flowers are pea-like in form, yellow in color, and produced in great abundance in late spring or early summer. The bark of the young wood is bright green.

Rose, Harrison's Yellow, (*Rosa hemisphearica* var. *Harisoni*) grows to a height of 6 feet or more. It is very hardy and bears bright yellow, double flowers in late spring or early summer.

Rose (*Rosa rugosa*).—There are two Russian types and a Japanese type. The former are considered hardier than the latter and are recommended for planting. So far we have tested only the Japanese type at Bozeman, where it has proved hardy. It grows from 4 to 6 feet high. The leaves are a very dark, glossy green. The flowers, single or semi-double, range from red to white and are two to three and one-half inches across. It is valuable for shrubberies or single specimens.

Sea Buckthorn.—See under Buckthorn.

Service Berry, Western, (*Amelanchier alnifolia*) is native to Montana, hardy, and desirable for shrubberies. It is valued for its white flowers in the spring and dark purple berries in the late summer and fall.

Snowberry (*Symphoricarpos racemosus*) is native to the State and does well under cultivation. It grows about 4 feet high. Small pink flowers are followed by large white berries which hang on well into winter.

Spiraea Van Houttei grows 5 or 6 feet high and is one of our best ornamentals. It is almost hardy and when given slight winter protection will not kill enough to interfere with growth or flowering.

DECIDUOUS TREES

Ash, Green, (*Fraxinus lanceolata*) is native to the eastern part of the State along the Yellowstone and lower Milk River valleys. There it grows from 20 to 50 feet high and when brought under cultivation makes a desirable tree for ornamental and windbreak purposes. It is hardy in most parts of the State and will endure considerable drought.

Ash, White, (*Fraxinus Americana*).—These trees, when 5 to 8 feet high, if not cultivated late in the season, appear to be hardy at this altitude (Bozeman) and may be recommended for planting. At lower altitudes in the State the white ash promises to be hardy at all stages of growth and should afford a good tree for street and park planting.

Birch, European White, (*Betula alba*) sometimes grows to a height of 80 feet. The bark on the trunk and larger branches is white. It is hardy and excellent where only partial shade is desired. It is not suitable for street planting.

Birch, Cutleaved Weeping, (*B. alba* var. *pendula laciniata*) has whiter bark than the European birch and long drooping branches. It is one of our most graceful and ornamental trees and is entirely hardy.

Box Elder (*Acer Negundo*) grows about 60 feet in height. It is valuable for shelter belts as it adapts itself to many adverse conditions. It is hardy and is adapted to all parts of the State where irrigation water is available but does not stand drought very well. It is not desirable for lawns where other trees can be grown because of its low, spreading habit, the ease with which it is broken by snow or wind and the insects which infest it. It is not a good street tree.

Elm, White, (*Ulmus Americana*) is hardy at the lower altitudes of the State and is a desirable tree for street and home ground planting. At higher altitudes with a short growing season it is not hardy. It requires a rather moist soil.

Larch (*Larix Americana*) is a desirable ornamental, growing to a height of 60 feet. It is hardy at Bozeman but is a doubtful tree for the prairies unless irrigation water is available.

Larch (*Larix occidentalis*) is native to the western part of the State and is hardy at Bozeman. It grows to a height of 150 feet. As the larches generally do better in moist soil, this tree is of doubtful value without irrigation.

Locust, Black, (*Robinia pseudacacia*) has pinnate leaves. The flowers are pea-like in form and the seeds are borne in pods. It grows 60 to 80 feet high. At Bozeman the tree is not hardy. At lower altitudes in the State with a longer growing season it can be grown.

Maple, Manchurian, (*Acer Ginnala*) is a small tree 20 feet high. The leaves turn red in the fall, making it desirable in shrubberies for autumn effects. At lower altitudes it is hardy. At higher altitudes it kills back when young but seems hardy as it grows older.

Maple, Norway, (*A. platanoides*) grows to 100 feet. It is a beautiful tree with a round symmetrical head producing dense shade. It does not grow as rapidly as the soft maple and has a tendency to form branches near the ground, which sometimes makes it undesirable as a street tree. At lower altitudes than Bozeman it is hardy. At Bozeman the greatest injury generally comes the first year after setting out. After that the injury is not sufficient to warrant discarding it from our list of trees.

Maple, Silver or Soft, (*A. saccharinum*) grows 120 feet high and is one of the fastest growing maples. The leaves are 4 to 6 inches long and deeply lobed, and are silvery on the under side. It grows best in rich, moist soils. It is not hardy enough to warrant planting at high altitudes. At lower altitudes than Bozeman, where the growing season is longer, the soft maple makes a desirable shade and street tree. Weir's cut-leaved maple is an improved variety of the soft maple and seems to be hardier than the others. It has deeper-lobed leaves and more drooping branches. At lower altitudes it will make a desirable ornamental tree.

Maple, Tartarian, (*A. Tataricum*) is a small tree or shrub growing 20 feet high. It is desirable for groups and shrubberies. It can be grown in any part of the State where the soil is fertile and irrigation water available.

Mountain Ash (*Sorbus Aucuparia*) grows into a round-headed tree from 20 to 40 feet high. It is hardy and desirable for its foliage and conspicuous red berries in the fall. The trunk of the tree is more or less subject to sun-scald on the south side during the winter and should be shaded at this season for four or five years.

Mountain Ash (*S. Americana*) is similar to the above. It is hardy and desirable for ornamental purposes.

Mountain Ash, Western, (*A. sambucifolia*) is native to Montana and grows into a small tree or shrub.

Oak, Bur, (*Quercus macrocarpa*) is native in parts of Montana where it is known as the scrub oak. It does not grow over 40 feet high. It is hardy but very slow-growing and not desirable as a street or shade tree because of its slow growth and small size.

Plums.—Some of the native plums are desirable in groups of shrubbery. Seeds of the same can be stratified in the fall and planted out in the spring, or they may be planted in the nursery row in the fall, in either case not allowing the seeds to dry out. They should be transplanted once in the nursery row before setting them in a permanent location.

Poplar, Balsam, (*Populus balsamifera*) is hardy and desirable for street planting. The wood matures early and the leaves drop before freezing weather. It is one of the best poplars. A variety (*latifolia*) of this poplar is very hardy and promises to be desirable for street and general planting.

Poplar, Certinensis, (*P. laurifolia*) is a rapidly growing, hardy tree. It is similar to the Carolina poplar in form of top. At this station it has given the best results of any of the poplars and promises to be good for street and ornamental planting.

Russian Olive or **Oleaster** (*Elaeagnus angustifolia*) is a small tree or shrub 20 feet high. The stems are usually spiny, the leaves lanceolate, light green above and silvery white below. It is suitable for hedges, screens, windbreaks, and groups. It endures considerable drought and alkali.

Willow, Diamond, (*Salix vestita*) is native to Montana and is hardy. It is considered valuable for fence-post material.

Willow, Golden, (*S. vitellina*) is hardy. It does not give a dense shade and the leaves and small branches fall throughout the summer, which makes it undesirable for a street and shade tree.

Willow, Laurel-Leaved, (*S. pentandra*) has glossy dark-green leaves. It is desirable for producing quick effects in shrubbery groups. It is more adapted to dry weather than other willows.

Willow, Russian Golden, (*S. vitellina*, var. *aurea*), has golden yellow bark and is superior to the common golden willow, with which it should not be confused. The young twigs have a reddish cast in the fall.

Willow, White or Gray, (*S. alba*) has not been tested at the higher altitudes of the State. It is considered a desirable tree for windbreaks on the prairies of North Dakota and will no doubt prove suitable for the prairies having climatic conditions similar to those of that State.

EVERGREENS

Arbor Vitae, Common, (*Thuya occidentalis*) has broad, scale-like leaves. It is adapted to evergreen hedges where there is plenty of irrigation water and no alkali in the soil.

Cedar, Red, (*Juniperus Virginiana*) is one of the largest junipers, sometimes reaching 100 feet. Native forms and most of the cultivated varieties are entirely hardy. Where it thrives it makes a desirable tree, but at Bozeman the growth is so slow that it seems advisable to plant it only where a large assortment of trees is desired. The junipers have more or less scale-like leaves, inconspicuous flowers, and berry-like fruits.

Pine, Austrian, (*Pinus Austriaca*) grows 40 to 50 feet high. It is hardy but does not seem adapted to open exposures like the Scotch pine.

Pine, Dwarf Mountain, (*P. montana*, var. *Mughus*) is a dwarf pine desirable in ornamental evergreen groups.

Pine, Jack, (*P. divaricata*) has not been tested on the station grounds at Bozeman. It has proved hardy in the Dakotas and should prove satisfactory in this State where the altitude is not too high. It does well on dry, poor lands.

Pine, Scotch, (*P. sylvestris*) is native to Europe and has proved hardy at this station. It is a desirable tree where irrigation water is available.

Pine, Western Yellow or **Bull,** (*P. ponderosa,* var. *scopulorum*) is hardy and a desirable tree, especially for shelter belts. It does well on dry soils.

Spruce, Colorado Blue, (*Picea pungens*) grows 80 to 100 feet high and has bluish-green to silver-white leaves. It is hardy and is one of our best ornamentals.

Spruce, Engelmann, (*P. Engelmanni*) is a desirable ornamental, growing 150 feet high. It is native to Montana. It is hardy and good for group planting on lawns and for shelter belts or windbreaks.

Spruce, Norway, (*P. excelsa*) is a very good tree for windbreaks. On the Dakota prairies, however, it has not proved as satisfactory as the Black Hills spruce and under similar conditions in this State it will probably be best to plant the latter. Young Norway spruce trees have not proved to be fully hardy at Bozeman but promise to be hardy when acclimated.

Spruce, White, (*P. alba*) is a valuable ornamental evergreen as it develops a good conical shape and does well on a variety of soils. The Black Hills spruce is a form of the white spruce that is adapted to the prairies of the Dakotas and should prove satisfactory on the prairies of Montana with similar climate. It is slower in growth, more stocky, and the needles are darker than the white spruce.

From Mich Agr Exp Sta —
Feb. 1920

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Comparative stands of rye planted October 10th and November 21st, 1918 and April 9th, 1919. Plats No. 1 and No. 5 were planted October 10th. Plat No. 2 was planted November 21st. Plats 3 and 4, which were planted April 9th, never headed out.

TREE PLANTING ALONG HIGHWAYS.

FORESTRY SECTION.

Many of the roads in the state can be greatly beautified by the planting of trees and the value of adjoining property increased thereby. While the state will doubtless ultimately see that our highways are properly planted, it is often to the advantage of landowners to plant trees immediately so as to secure early results. An Act passed by the last session of the Legislature, Act No. 36 of the Public Acts of 1919, authorizes the State Highway Commissioner and the State Board of Agriculture to select and plant ornamental and nut-bearing trees along highways upon which state reward has been paid or earned, the trees for planting to be supplied by the Agricultural College or the Public Domain Commission. The Act provides that in no case shall such trees be planted except with the consent of the owner of the adjoining property, and that the Highway Commissioner shall establish rules and regulations for the uniform planting of trees under the Act. The Act also provides that any owner of land bordering upon a highway upon which State reward has not been paid may plant approved ornamental or nut-bearing trees along the line of the highway and shall receive annually a credit of five cents upon his highway repair tax for a period not to exceed five years for each tree so planted and in good growing condition not less than six feet high and not less than 20 or more than 40 feet apart.

The Michigan Agricultural College and the Public Domain Commission are authorized to raise trees for planting and to sell them at nominal cost to counties, cities, villages, and citizens of the state for highway planting and also for planting in state parks and other public places.

The Forestry Department of the College has at the present time a considerable number of trees suitable for this purpose.

Mistakes made in the selection of species of trees for highway planting, may not be discovered in a decade. In order to make such mistakes less common and to safeguard the public against errors in spacing of trees and selection of species for our highways, the following simple principles are offered:

1. Use only such trees as are comparatively free from destroying insects and diseases.

This will eliminate at once such trees as the black locust, the elm, the fruit tree, and any others which may have local enemies.

2. Use trees adapted naturally to the soil and climate of the locality.

For example, a burr oak section should not have its highways planted with pine nor should a red pine section be planted to burr oaks.

3. Pure planting of one species should not be used for distances exceeding one mile.

4. Use trees that are native to the locality wherever possible. They give quick results and furnish variety.

5. Along roads that have been entirely denuded of tree growth, plant a temporary and a permanent tree alternately. An example would be: The sugar maple for permanent and the box elder for quick results and removal later when the sugar maple had attained useful size.

6. Space trees on the highway according to the spread of their crowns at maturity. Taking the sugar maple as an example with a spread of crown of 35 feet from the stem we see that a spacing of less than seventy feet will permit the interlacing of branches, which is not desirable with highway trees; therefore, a safe spacing for sugar maple is 85 feet with trees on the opposite side of the highway to alternate. A planter may determine the safe highway planting distance for any species by measuring the crown spread of a fully mature specimen of that species and adding ten feet to the result.

In general the soil variation gives to the highways of Michigan an opportunity of rare worth for the production of a large variety of trees and shrubs of highly ornamental and utilitarian value.

BROAD-LEAVED EVERGREENS FOR OHIO PLANTERS

W. E. BONTRAGER

Native evergreens satisfactory.—Those who have visited England and continental Europe or the Pacific coast of our own country deplore the scarcity of broad-leaved evergreens that succeed in eastern North America as compared with the luxuriant growth of glossy, lustrous foliage that is secured in the regions named. This condition is largely due to climatic reasons, as many of the finer species, such as rhododendrons and laurels, are scarcely more than half hardy and may only be expected to do well in countries where mild, open winters are the rule. It is only under the favorable conditions prevailing in England and France or in the states of Oregon and Washington that we may find the more desirable named varieties of rhododendron growing and flowering with any considerable degree of success. Nevertheless, we have in this country a limited number of native species known to withstand the rigors of our severest winters and to grow reasonably well wherever proper soil conditions and other requirements are supplied.

The cultivation of the finer grafted rhododendrons should only be undertaken by the amateur in a small way unless one is prepared to supply almost exactly the needful conditions. Most plantings of them on home lawns have been established in unsuitable soil or exposed to the full sunlight, with the result that poorly nourished plants eke out a dreary existence and contribute but little to the enjoyment of the owner. Occasionally on some extensive estate or in a well-managed park or cemetery will be found a clump that is entirely at home, growing vigorously, but in such cases the secret of success may generally be traced to the efforts of some experienced professional gardener.

Requirements for successful culture.—The requisites for the successful cultivation of nearly all broad-leaved evergreens are a cool, moist, well-drained soil, in connection with a shaded or semi-shaded position; and in the case of those species belonging to the heath family, such as rhododendrons and kalmia, it is imperative that the soil be an acid one, almost entirely free from lime. This acidity may be maintained by annual heavy mulchings with oak leaves. A mulch of maple or other leaves it not so good, as most other kinds of leaves become alkaline in the process of decomposition and serve to neutralize rather than to maintain the very essential acid condition.

The Mountain Laurel—Native to the Allegheny mountain region are found a few very desirable broad-leaved evergreens, worthy of general distribution and trial. At the head of the list undoubtedly stands the Mountain Laurel (*Kalmia latifolia*), a rugged, spreading species that makes a shapely, picturesque plant of great landscape value. Its foliage is unusually clean, glossy and fresh-looking. The hardiness of the Mountain Laurel is not to be questioned. In May well-established plants are enveloped in a mass of bloom, at first a deep pink and later turning white, that persists for many days. The Mountain Laurel grows naturally in various parts of Ohio and has been under observation at the Experiment Station for quite a number of years. The plant appears at its best when grown in the mass, and for colonizing in shaded cemeteries, along the north side of buildings or in open groves it has no real rival. Probably the nearest approach to it in points of excellence is *Rhododendron catawbiense*, another native of the Alleghenies, which has also been grown at the Experiment Station for a considerable period. This species is a handsome, dark green plant growing 3 to 6 feet high, that bears rather freely masses of flowers in a somewhat trying shade of magneta, or dull, light purple. For those who wish to make beds and masses of entirely hardy rhododendron, R. catawbiense, should be given the preference over all others.

The Great Laurel (*Rhododendron maximum*), of the Allegheny region, is a larger species than either of the foregoing, often reaching a height of 20 feet, which flowers later in the season, generally near the end of June. Several plantings of this rhododendron have been a subject of study at the Ohio Station for a reasonably long time, under conditions thought almost exactly to supply their natural requirements. The outcome has not been entirely satisfactory, probably because the plantings were made with large plants collected in the mountains at somewhat too late a time in the season. These plants were not located in their permanent beds until the middle of June. Experience derived from this venture seems to indicate that it is safer to procure thrifty young nursery-grown stock than to place reliance on over-grown plants brought in from the wild.

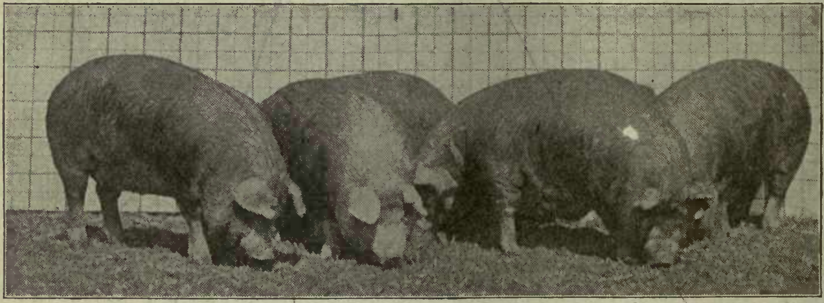
Other varieties.—Two other broad-leaved evergreens which have done well at the Ohio Station are *Mahonia aquifolia* and Mountain Fetter-bush (*Andromeda floribunda*). The Mahonia has good foliage quite similar to that of holly, making a plant 3 to 5 feet high that is rather spreading in outline. Numerous small yellow blossoms borne closely to the stems are succeeded in autumn by conspicuous blue berries. The Mahonia is an excellent thing that can only be grown in shade, unfortunately, as undue exposure to sunlight and consequent freezing and thawing in winter causes unsightly browning of the foliage. However, the plant is perfectly hardy and in spring quickly puts out a new growth of leaves. The Mountain Fetter-bush is an interesting iron-clad subject whose leaves are not browned or injured any way in winter, even when exposed to full sunlight. The plant is a low, compact, round-headed one whose bloom spikes, closely resembling those of lily-of-the-valley, appear in autumn and burst into full flower very early in spring.

When well established Mountain Laurel is a prolific bloomer

For carpeting under the shade of trees the familiar, old-fashioned myrtle (*Vinca minor*) and *Euonymus radicans* are two valuable vines. *Pachysandra terminalis* is an excellent perennial plant, spreading slowly, that furnishes a neat mat of good foliage throughout the year. Except in very sheltered nooks and corners on north or west walls, English ivy has not given satisfaction in this country, but when protected by a mulching of straw, leaves or evergreen boughs it is sometimes utilized as a covering for graves. A new plant which it is thought may to some extent supply the need for a satisfactory evergreen wall covering is Evergreen Bitter-sweet (*Euonymus vegetus*), which so far has been tested only in a limited way but promises much for future usefulness.

Pigs self-fed corn and ground soybeans for 14 weeks: average initial weight, 54.2 pounds; average final weight, 168.8 pounds

Pigs self-fed corn and soybean oilmeal for 14 weeks: average initial weight, 54.2 pounds; average final weight 184.2 pounds



Pigs self-fed corn and tankage for 14 weeks: average initial welght, 53.5 pounds; average final weight, 205.7 pounds

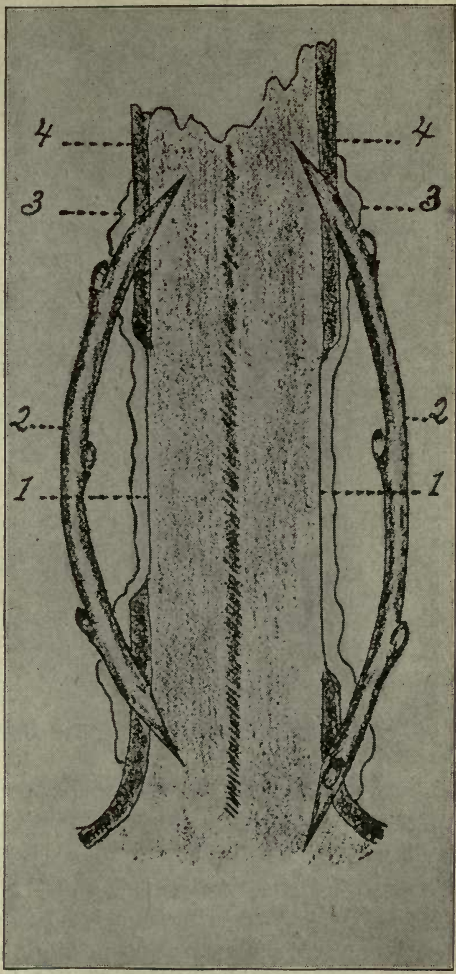
RODENT PROTECTION FOR FRUIT TREES

Treatment For Injured Trees; How To Make Grafting Wax

DEPARTMENT OF HORTICULTURE

Rodents cause unusual injury.—Because of the deep snow covering most of Ohio during the winter, rodents have caused unusual injury to fruit trees. The snow has been 8 to 12 inches deep with a crust on top, thus giving the rabbits a chance to gnaw the trees a distance considerably above the ground, and in some cases there has been injury to the lower limbs. While the rabbits have been working havoc above the snow the mice have been busy beneath the snow and on top of the ground. Reports of injury to trees as old as 6 years have reached the Station and requests for information as to how to treat injured trees are coming from all sections of the State.

A few measures of prevention as well as methods of treating trees already injured are here suggested.



Bridge grafting in general
1. Wound 2. Scion
3. Wax 4. Bark

Mechanical protectors. The Station has followed the plan of placing a half bushel or more of cinders around the base of newly-planted trees early in the fall and enclosing the trunk of the young trees in cylinders made of galvanized wire netting, three or four meshes per inch. This cylinder ought to be 5 or 6 inches in diameter and 18 inches high. The cylinder is imbedded in the cinders to a depth of 2 inches.

By renewing the cinders each fall and adjusting the cylinders this method of prevention will carry the trees up to a period when most of the danger is past; the initial cost is rather high but it is more permanent than any other method.

Repellents.—Fresh blood applied in the fall and again in midwinter serves as a repellent against rabbits. Trees may be rubbed with fresh meat or liver as a means of preventing rabbit injury.

Wound 2 years after bridge grafting

Many other remedies have been suggested and used for protection against rabbits. Some of these recipes are complicated, most of them frequently containing highly-scented drugs.

Commercial lime sulphur, full strength, painted on the trunks of trees twice during the winter has proved effective in some cases. Sulfocide has also been used effectively.

Remedies for injured trees; grafting.—After a tree has been injured the remedy to be applied will depend upon the extent and height of the damage.

If the injury is beneath the ground and the tree completely girdled it is better, in most cases, to remove the tree and replant. If the injury is high enough above the ground to permit bridge grafting, trees completely girdled may be saved if the work is done before growth starts and the wound is covered with grafting wax or some substance to prevent evaporation of moisture.

If the injury is 18 to 24 inches above the ground and the tree is not over 2 or 3 inches in diameter the tree can be sawed off below the wound and a scion inserted in the top of the stub, using the cleft graft.

Bridge grafting is done by inserting one end of a scion a few inches below the wound and the other end a few inches above the wound. Scions should be cut a little longer than the span to be bridged so that they will be slightly curved. The scions should be inserted firmly in slanting incisions made by a chisel, being careful that the cambium layer, or inner bark, of the scions unites with the cambium of the tree. After the scions are inserted, grafting wax should be placed carefully around the incisions and the wound should also be waxed.

The number of scions required depends upon the size of the tree. One scion every 2 or 3 inches around the tree will be sufficient. Bridge grafting may also be used to good advantage on trees only partially girdled.

Wounds of any size will heal much faster if covered with grafting wax, lead paint, or even clay as soon as the injury is discovered.

Another plan of taking care of trees that are girdled some distance from the ground is to cut them off beneath the wound and depend upon a sprout coming from beneath the wound to make a new top for the tree. Care must be used in this practice that the sprout comes from above the original graft.

Where cinders and wire netting are not at once available more temporary precautions may be utilized. Mice rarely come out in the open to work, hence the grass, weeds and all trash should be cleared away from the trunk of the tree for a foot or more in all directions. The ground should be firmed with a tamper to fill runways or burrows and a few shovelfuls of fresh soil slightly mounded around the base of the tree. Wood veneer, stripped corn stalks cut in 2 feet lengths, building paper, common heavy wrapping or even newspaper bound firmly about the stem of the young trees will give protection from the rabbits for one season or until more permanent material may be used.

Grafting wax formula.—The following is a standard recipe for grafting wax:

Melt together four parts (by weight) of resin, two parts of beeswax and one part of tallow. Pour the mixture into a pail or tub of cold water. As the mass begins to cool so that it can be handled, grease the hands with tallow and pull and work the lump of wax until it becomes quite light in color. It may then be formed into small balls or sticks for convenient use. This wax will keep in good condition indefinitely.

PUBLICATIONS OF THE OHIO AGRICULTURAL EXPERIMENT STATION

The publications of this Station are now issued in three series, namely:

1. The Monograph Bulletin, each number of which is a record of progress in a single line of investigation. This series is a continuation of both the ordinary and the "Technical" series heretofore issued and is largely technical in character.

2. The Monthly Bulletin, each number of which contains several brief and timely reports of progress in different phases of the Station's work, including nontechnical abstracts of the Monograph Bulletins.

3. A Weekly Press Bulletin, containing brief notes on the Station's work, prepared for newspaper circulation. The more important of these notes are republished in the Monthly Bulletin.

These publications are sent free on request. The addresses of those who request that their names be placed on the mailing list will be entered for the Monthly Bulletin only, unless either of the other series is definitely requested. Address Mailing Room, Experiment Station, Wooster, Ohio.

RECENT MONOGRAPH BULLETINS

No. 321—Tomato diseases in Ohio: Descriptions and control measures recommended for rhizoctonia, Fusarium wilt, bacterial wilt, stem rot, leaf spot, blight, anthracnose, rot, "leak," leaf mold and other diseases common to growing tomatoes.

No. 322—Feeding experiments with laying hens:—Range vs. confinement, variety vs. simple rations, various amounts of protein, methods of feeding, date of hatching, corn vs. wheat.

No. 323—County Experiment Farms in Ohio: Annual reports for 1916 and 1917.

No. 324—Ohio weather for 1917.

No. 325—Thirty-seventh annual report: Projects under investigation, financial statement for 1917-1918, index to technical bulletins.

No. 327—Clover vs. alfalfa for milk production: Discussion and summary tables of feeds, production, groups of cows used and individual summaries.

No. 328—Livestock vs. grain farming: Relative profits in livestock and grain farming, labor required in both types, crops and fertility considerations.

No. 329—The peach tree borer: Life history and habits, natural enemies, testing of remedies for control, recommendations for control.

No. 330—The mineral metabolism of the milch cow: Minerals needed by dairy cattle, feeds that supply minerals, the practice of feeding bone flour, the necessity of legumes in the ration.

No. 331—The farmers' elevator movement in Ohio: Early history, location, methods of operating and suggestions for organizing companies.

No. 332—Destructive insects affecting Ohio shade and forest trees.

No. 333—Apple blotch, a serious fruit disease.

No. 334—Dairy production in Ohio: Results of cooperative tests, costs in production and suggested methods of fixing milk prices.

No. 335—Effect of age of pigs on the rate and economy of gains.

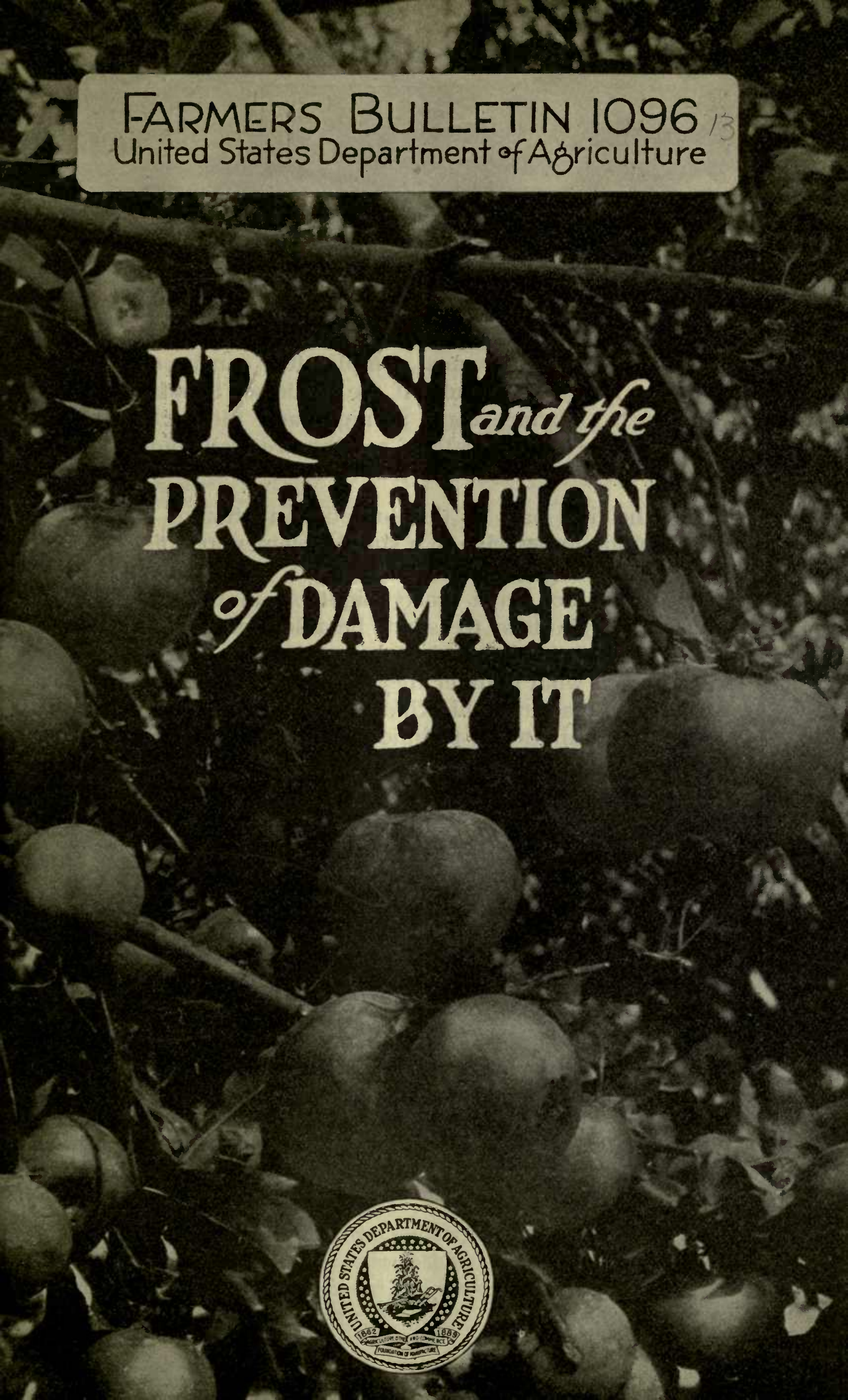
No. 336—The maintenance of soil fertility: A quarter century's work with manure and fertilizers.

No. 337—Ohio weather for 1918.

No. 338—Thirty-eighth annual report: Projects under investigation, financial statement for 1918-1919, index to technical bulletins.

FARMERS BULLETIN 1096 13
United States Department of Agriculture

FROST and the PREVENTION of DAMAGE BY IT



ALL FROST PROTECTION METHODS, from the simplest to the most complicated, can be carried on more successfully if the processes by which the earth's surface cools at night and the factors which influence the rate of cooling are well understood.

In the first part of this bulletin an attempt has been made to describe in a simple, elementary manner the changes that take place at and near the earth's surface on a frosty night, so that persons protecting plants or trees may be able to understand how their protective devices operate to prevent damage and in what manner they are most efficient. In treating a matter of this kind it is practically impossible to eliminate all technical terms, but so far as possible these have been carefully explained in simple language.

The larger portion is given over to a discussion of the various methods and devices now being used for protection against frost, together with a chapter on temperatures injurious to plants, blossoms, and fruit.

Contribution from the Weather Bureau
C. F. MARVIN, Chief
Washington, D. C. April, 1920

Prepared by
FLOYD D. YOUNG
Meteorologist, Weather Bureau

FROST AND THE PREVENTION OF DAMAGE BY IT.

CONTENTS

FROST DEFINED

WHAT IS FROST?

The words "frost" or "hoar frost" are used to designate the deposit of feathery ice crystals which usually form on the ground or other exposed surface whose temperature has fallen to 32° F., the freezing point of water, or lower. In a larger sense, the occurrence of any temperature of 32° F. or lower, whether accompanied by a deposit of ice crystals or not, is called a frost.

Frosts are spoken of as light, heavy, or killing, depending on the degree of damage to growing crops. Since the same temperature that kills young tomato plants may not injure fruit blossoms, a frost that would be called "killing" by one person may be regarded as "light" by another. During the growing season a period of extremely cold weather accompanied by strong winds, when the air for a considerable distance above the earth is chilled, is sometimes called a "freeze." True frosts occur only when the surface air is relatively calm.

In order to understand the underlying principles of frost protection it is necessary to know something of the methods by which the ground surface and lower air cool during the night.

HOW FROST IS FORMED

Whenever two objects or portions of the same object are unequally heated, the colder always gains in temperature at the expense of the warmer, the tendency being to equalize the temperature throughout every portion of the bodies. The interchange of heat is accomplished in two ways, radiation and conduction, each of which will be discussed separately as it bears on the matter of the occurrence of frost.

Radiation.—The heat and light from the sun come to us through space in a form of wave motion called radiation. The atmosphere offers considerable obstruction to the passage of these waves. Even when the sky is very clear, rarely more than 65 per cent of the radiation penetrates to the surface of the earth, the part absorbed being expended in raising the temperature. The region near the upper limits of the atmosphere is one of intense cold. As the sun, having a much higher temperature than the earth, radiates heat to the earth, so from the surface of the earth heat is radiated to the much colder upper limits of the atmosphere.

The radiation of heat from the earth is continuous both day and night when there are no clouds or other obstructions between the earth and the upper atmosphere. During the day the amount of heat received from the sun is so much greater than the amount lost by radiation from the earth that the temperature rises. After the sun sets, however, no heat is received to counterbalance the loss by outgoing radiation and the temperature falls.

Conduction.—Heat may be interchanged between different portions of the same body, or between two separate bodies in actual contact, by conduction. When one end of a bar of iron is held in a fire, the end away from the fire soon becomes too hot to hold in the hand. The heat is transferred from the hot portion of the bar to the cooler portion by conduction. The shortness of the time taken for the heat to reach the cooler end of the bar indicates that iron is a relatively good conductor of heat. On the other hand, one end of a stick of wood can be held in the fire until it is completely consumed without the other end becoming very warm; therefore wood is a poor conductor of heat. Of course, if the stick ceased to burn and the heat in the burning end were not lost, the heat in the warm end would eventually be distributed equally throughout the stick. Both the soil and the air are very poor conductors of heat.

During a clear, calm day the temperature of the ground surface is raised by the heat received by radiation from the sun and the air in immediate contact with the ground becomes warmed by conduction. Since the air is so poor a conductor, the increased temperature of the ground is imparted to only a very thin layer of air at first. However, as soon as a small portion of this layer becomes warmer than the air above and around it, its density is lessened and it is forced upward and replaced by the cooler and denser air near by or above. This air is also warmed in turn by conduction from the ground and rises to make room for more cool air. The heated air continues to rise until it reaches a point where its temperature is the same as that of the air surrounding it. This process continues until, near sundown, the temperature of the air is highest near the ground and decreases at a more or less uniform rate with increased distance above the ground up to a height of a thousand feet or more.

After the sun goes down the ground cools rapidly through radiation, and its temperature soon falls below that of the layer of air in contact with it. As soon as this occurs the surface air begins to lose heat to the ground by conduction. The air near the ground now becomes cooler than the air above and its density becomes increasingly greater. Instead of rising, as did the surface air during the day, its increased density tends to keep it in contact with the ground. Thus over a level plain on a clear, calm night we find a relatively thin layer of cold air near the ground with an increase in temperature up to an altitude of between 300 and 800 feet.

Air Drainage.—Over gently sloping ground the force of gravity tends to cause this thin surface layer of cold air to move down the slope and to gather in depressions in somewhat the same manner as water. The similarity between the flow of water and of air down a slope is inexact, however, because of the difference between the physical characteristics of air and water. Water is a practically incompressible liquid; therefore neither its volume nor its density is much affected by a change in pressure. Air is a compressible gas and its physical condition is influenced greatly by such a change. The atmosphere exerts a pressure at sea level of about 15 pounds to the square inch. Because of its compressibility, the density of the air decreases rapidly with increase in altitude. In accordance with a law governing the behavior of gases, a decrease in density is accompanied by a decrease in temperature and an increase in density causes an increase in temperature. When air moves downward along a gentle slope or a steep hillside, its altitude is constantly decreasing and its pressure and density are constantly increasing. The increase in density causes an increase in temperature (heating by compression) at the rate of about 1.6° F. for every 300 feet decrease in elevation and an increase in elevation causes a decrease in temperature (cooling by expansion) at the same rate, provided there has been no loss or gain of heat from other sources.

Over a gently sloping plain or valley floor it is possible for the cold surface air to drain down the slope in much the same manner as water, as the vertical movement of the air takes place so slowly that the heating effect due to decrease in altitude is more than offset by the cooling due to contact with the ground which has been cooled by radiation. When we are dealing with a steep hillside, however, movements of the surface air are more complex and have little similarity to the flow of water down the same slope.

Like the more nearly level lower ground, the slopes and summits of hills and ridges lose their heat rapidly after sundown through radiation, and their temperature falls. The air in immediate contact with them also cools through conduction so that it is soon cooler

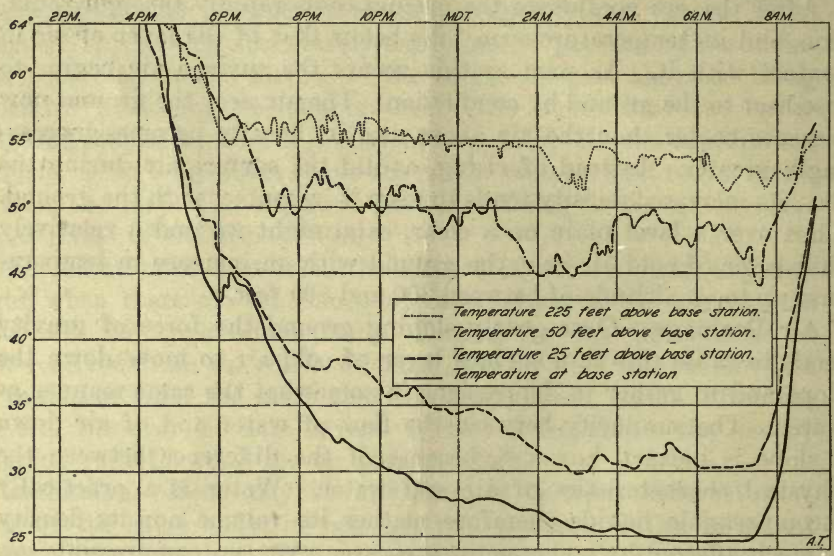


FIG. 1.—Continuous records of the temperature from 4 p. m. to 9 a. m. at the base and at different heights above the base of a steep hillside, showing the great differences in temperature that sometimes develop on a clear, still night. Although the temperature at the base was low enough to cause considerable damage to fruit, the lowest temperature 225 feet above on the slope was only 51°. Note that the duration of the lowest temperature was much shorter on the hillside than at the base.

than the air at some distance out over the valley, but at the same elevation.

If this cooler air in contact with the hillside begins to flow downward directly along the surface of the ground, its altitude will be decreasing more or less rapidly, according to the steepness of the slope, and its density will be increasing. If no further cooling takes place, it will be surrounded by air increasingly colder as it nears the valley floor, while its own temperature tends to increase because of the compression it suffers. As soon as a position is reached where it is warmer than the air surrounding it, its downward movement will be checked and it will tend to rise again until its temperature is the same as that of the air surrounding it. (See fig. 1.)

The drainage of cold air down a valley floor is usually interfered with considerably by outside influences. As soon as the flow begins there is more or less mixing of the cold lower air with the warmer upper air and inequalities in barometric pressure over whole regions may temporarily prevent the flow or even reverse its direction for short periods. Local winds of slight velocity and covering a very limited area often cause a mixing of the air that causes the surface temperature to rise suddenly from 5° to 10°. It is not often possible to know in advance that the drift of the air on a valley floor will continue from one direction during a cold night, though there may be one particular direction from which it very seldom comes.

Effect of Water Vapor on Rate of Cooling.—Water vapor is the most effective of the various gases present in the atmosphere in obstructing radiation of heat from the earth. Therefore, the amount of water vapor present in the atmosphere above a given locality has considerable influence on the rate of fall in temperature at that place during the night; the temperature falls more slowly when the humidity is high than when it is low, other conditions being the same.

The amount of invisible water vapor in the atmosphere varies greatly at different times. At a given temperature only a certain maximum amount can be present. If, when the maximum amount is present, the temperature is lowered, a certain portion of the water vapor is changed to liquid or frozen water, as the amount of water vapor which can be present in the air is greater when its temperature is high than when it is low. No matter how dry the air under natural conditions may be, if its temperature be lowered sufficiently, a point will be reached where the invisible vapor will begin to appear in a liquid or frozen form. The temperature at which this condensation begins is called the dew point. The drops of moisture which appear on the outside of a pitcher of ice water on a warm day are formed through the chilling of the air in contact with the pitcher. These droplets begin to appear on the pitcher as soon as its temperature has reached the dew point.

The actual amount of water vapor in the air expressed in terms of weight per given volume of air, is called absolute humidity. With a given dew point the absolute humidity is always the same; therefore to determine the absolute humidity it is only necessary to find out what is the temperature of the dew point.

As a general rule the temperature of exposed objects falls more or less steadily after sunset until it reaches the dew point, at which time the invisible water vapor in the atmosphere begins to be deposited on them. If the dew point is above 32° F., the freezing point of water, dew is formed; if it is 32° F. or lower, frost forms. Since dew or frost does not begin to form until the temperature of the ground or other object reaches the dew point, it is apparent that if the dew point is very low, the temperature may fall low enough to cause considerable damage without the formation of any frost. For example, if the dew point is 18° F. and the lowest temperature reached during the night is 24° F., there will be considerable damage to growing crops without any frost whatever. This phenomenon, often called a "black frost," is of rare occurrence in most localities.

Another factor that has great influence on the amount of fall in temperature during the night is the liberation of latent heat in the formation of dew and frost. A definite amount of heat is required to raise the temperature of a given amount of water to the boiling point without vaporizing any of it. After the boiling point is reached, another definite amount of heat is required to convert this water into water vapor, the temperature of the water remaining unchanged during the vaporizing process. This latent heat, stored up in the water vapor, is released whenever the water vapor is again changed to a liquid state. A portion of the sun's heat during the day is expended in evaporating moisture from the ground and from the leaves of plants. When the dew point is reached at night and vapor is condensed, its latent heat is given up. The amount of heat given up on a particular night depends on the amount of moisture precipitated. Obviously, the greater the amount of moisture in the atmosphere, the more will be condensed, provided the temperature falls below the dew point. When the dew point is high, the latent heat given off in the formation of dew is often sufficient to check the fall in temperature almost entirely. Generally speaking, therefore, other conditions being equal, the higher the dew point in the evening the less danger there is of the occurrence of a damaging frost.

WHEN TO EXPECT FROST

The weather in the latitude of the United States is controlled by atmospheric disturbances of great size and varying intensity, which follow one another across the country, moving from west to east. These disturbances are of two types, one of which is marked by low barometer, overcast skies, and rain or snow; the other by high barometer and clear skies.

The main factor in the occurrence of frost is radiation of heat from the earth. When heavy lower clouds cover the sky, they act as a blanket and prevent radiation to the upper limits of the atmosphere, making impossible the occurrence of a true frost. A moderate wind is also generally effective in preventing frost. The formation of a thin layer of cold air near the ground is prevented on a windy night by the mixing of the surface air with the warmer air above.

The important requirements for the occurrence of frost, a clear sky and little wind, are present during the passage of an area of high barometer. As the first-mentioned type of disturbance, the area of low barometer with overcast skies and rain, nearly always precedes the area of high barometer, the saying in many sections of the country, "Three days rain and then a frost," has some basis.

During the passage of a well-defined area of low barometer the radiation from the sun is more or less completely cut off by heavy clouds and the ground is not warmed much during the day. If rain has fallen, the evaporation from the wet ground uses up a great deal of heat and this also tends to keep the temperature low during the day. Therefore, on the first clear night after a rain during the frost season the temperature at sunset is likely to be within 15° or 20° of the freezing point and not much cooling by radiation is necessary to form frost, although frost is not expected in many cases on the first night on account of wind conditions.

Though the moisture in the ground after a rain tends to prevent warming of the ground during the day, it also tends to prevent a large fall in temperature during the night. The water vapor taken up by the atmosphere from the wet ground diminishes radiation. When the dew point is reached the latent heat given up checks the rate of cooling still more, and when the freezing point is reached the conversion of the ground moisture into ice also liberates heat and aids in preventing a further fall in temperature.

Before the second night after the rain the surface of the ground has usually dried out considerably. The dew point is likely to be lower and a more damaging frost is likely to occur at that time. Before the third night the day temperature has usually risen high enough to make unlikely the occurrence of a heavy frost on the Pacific coast, while in the central and eastern part of the United States frost may occur as late as the fourth night if the high pressure area is well defined and moves slowly.

Large bodies of water exert a modifying influence on the climate of localities to the leeward and such localities do not often suffer much damage from frost. A light wind blowing from a large body of water is generally more or less laden with water vapor, which cuts down the rate of radiation; and as the temperature of the water is usually considerably above freezing, the temperature of the air passing from it to the land is high enough to prevent the formation of frost.

Rivers often give up a large amount of moisture to the surface air so that when the temperature falls to the dew point a fog forms which covers a part or all of the lower land in the valley, cutting off radiation and preventing a further fall in temperature.

In valleys near the ocean, fog sometimes drifts in from the water toward morning and prevents a damaging frost. On nights with fog the hillsides are practically always colder than the lowlands unless the fog extends high enough to cover both hillsides and valley floor.

INFLUENCE OF SOIL AND VEGETATION ON MINIMUM TEMPERATURE

In experiments carried on in the cranberry bogs of Wisconsin, Prof. H. J. Cox found differences of from 5° to 10° F. between minimum temperatures registered on the surface of level ground at two points within 6 feet of each other. The ground at the warmer station was bare, while that at the colder station was covered with spaghnum moss. The soil at both points was peat. At a height of 3 feet above the ground this difference in temperature disappeared.

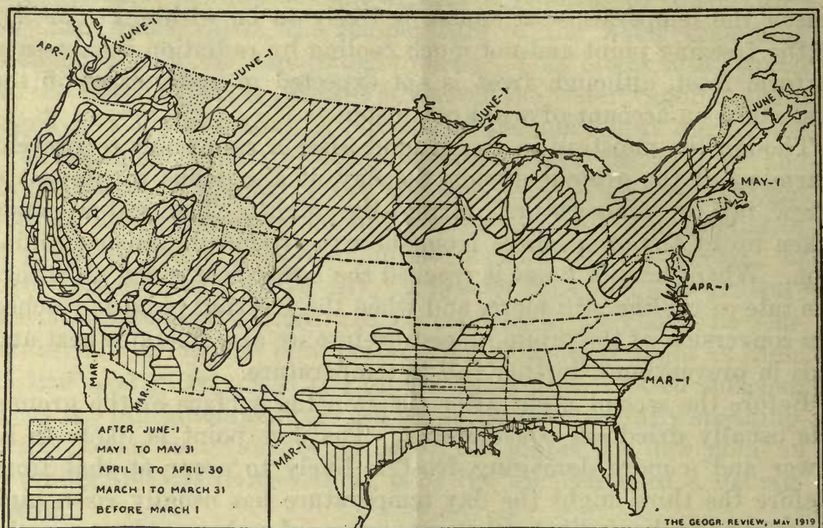


FIG. 2.—Average dates of last killing frost in spring.

Prof. Cox attributes this difference in temperature to unequal warming of the bare and moss-covered soil during the day and unequal conduction of heat to the surface from below during the night. The soil at the cooler station was shaded by the moss and a large part of the heat received during the day was expended in evaporating water from the plants, while at the warmer station the sun shone directly on the soil, warming it to a greater depth. At night the heat absorbed during the day was slowly conducted to the surface of the bare ground while most of the smaller amount of heat absorbed by the moss-covered ground was prevented from reaching the thermometer because of the intervening moss, which is a poor conductor of heat.

It was also found that the temperature often fell several degrees lower at night over wet ground than over dry ground, because of the heat expended in evaporating moisture from the wet ground during the day. By covering the bogs with coarse sand, the moisture is prevented from rising to the surface from below, and cooling by evaporation is checked. By keeping the bog free from weeds, draining, and sanding, damage by frost may be greatly lessened.

PROTECTION FROM FROST

Since a crop which represents the results of the labor and care of an entire season may be destroyed by frost in a single night, various methods of protection against frost have been practiced for centuries in different parts of the world.

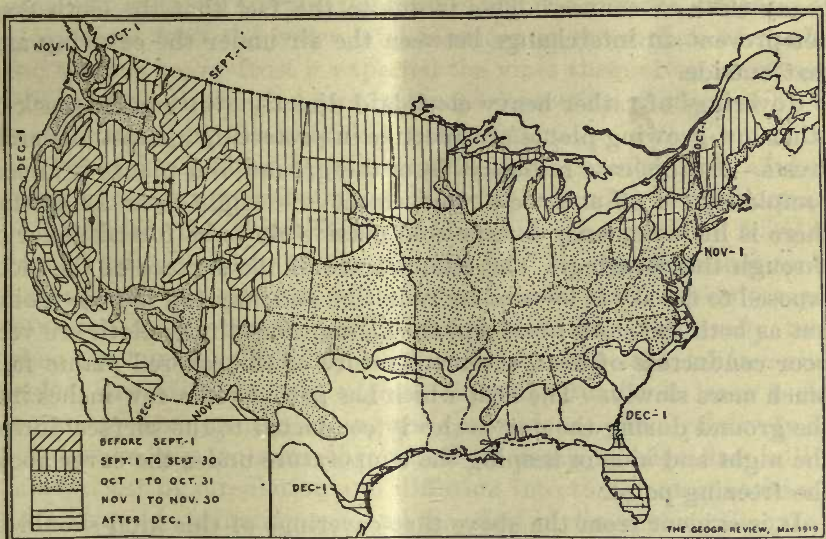


FIG. 3.—Average dates of first killing frost in fall.

The three general principles used in frost protection devices in the United States are:

(1) Conserving heat, (2) Mixing or stirring the air, and (3) Adding heat.

CONSERVING HEAT

The most important method by which the ground cools during the night is radiation. If it is possible to prevent radiation or reduce it sufficiently, the ground heat will be conserved and there will be no damage. This may be partially accomplished by covering the ground or plants with various materials.

Covering with Glass.—Glass is one of the best materials known for screening plants and preventing frost damage, since it is almost impervious to the waves of outgoing radiant heat from the earth, but allows the incoming heat from the sun to pass through it freely. The expense of covering with glass is too great to allow of its use except for the more expensive plants and flowers.

Cloth Screens.—Experiments have been carried on in California and elsewhere to determine the value of a covering of cloth over orchards and over individual trees. When an acre or more of orchard is thus covered, the minimum temperature may be from 2° to 4° higher inside the covered area than outside, if there is little air movement. In experiments carried on in cooperation by the Weather Bureau and the Southern Oregon Experiment Station of the Oregon Agricultural College, it was found that cloth coverings over small areas of orchard or over individual trees do not have an appreciable effect on the temperature, even when the coverings are of heavy cloth or canvas. This is due to the fact that the cloth does not prevent an interchange between the air under the covering and that outside.

Coverings of rather heavy cloth laid directly over garden truck or other low-growing plants are effective in protecting against moderate frosts. In this case radiation from the ground and plants is almost completely cut off and the air movement is so slight near the ground there is little tendency for the cold outside air to be forced under or through the covering. The temperature of the surface of the cloth exposed to the sky is lowered by radiation and may fall to a low point, but as both the cloth itself and the air underneath the cloth are very poor conductors of heat, the temperature of the covered plants falls much more slowly. The heat which has penetrated a few inches into the ground during the day is slowly conducted to the surface during the night and aids in keeping the temperature under the cover above the freezing point.

It is evident from the above that coverings of this kind should be placed early in the evening when a frost is expected, before much of the heat accumulated in the soil during the day has been lost. Tin cans or other metal coverings should not be used to protect plants from frost damage. Metals are good radiators and conductors of heat and the temperature is likely to fall nearly as low under a covering of this kind as in the outside air.

Lath Screens.—Screens made of laths fastened together with wire (the spaces between them being about the width of the laths) have been used in Florida and California to protect orchards. These screens serve not only to diminish outgoing radiation during the night but also as a shade from the sun. About three-fourths of the sky is screened by a covering of this kind. By placing the laths in north and south directions the direct rays of the morning sun are completely cut off, which permits of a slow thawing of blossoms and fruit after a heavy frost. This reduces the amount of injury.

Orchard heaters burned under screens of lath or cloth are more effective in raising the temperature than is the case when they are burned in an uncovered orchard.

Other Methods.—Paper covers may be used to protect small individual plants or large paper strips may be used to protect gardens against light frosts. Generally speaking, paper coverings do not afford as much protection as those made of cloth.

Young potatoes and garden truck are sometimes protected by plowing a furrow between the rows and covering the plants with soil.

Cranberry growers in the marshes of Massachusetts, New Jersey, and Wisconsin flood the marshes with water from large reservoirs when frost is expected. For protection against a light frost it is generally sufficient to raise the level of the water in the ditches. For a moderate frost the water level is raised to the surface of the bog and when a heavy frost is expected the vines themselves are covered with water. In the first two instances protection is afforded by the heat given off by the relatively warm water.

Devices for Adding Moisture to the Air.—Smudge fires of damp straw or manure have been used to create a blanket over the area to be protected, the object being to decrease the radiation from the ground rather than to add heat to the air. It is possible that such a method may be successful when the air is calm and is already nearly saturated with moisture. However, heavy frosts generally occur when the humidity is fairly low and a perfectly calm surface air is seldom met with on cold nights; there is usually at least a slow movement down gently sloping valleys or plains. In a relatively dry atmosphere any moisture thrown off by damp smudge fires will be rapidly lost by circulation and diffusion into the great quantities of air above and surrounding it, and the effect in diminishing the rate of radiation will be very small. At the same time, if an effective blanket of moisture could be spread over the orchard, a slight breeze would carry it steadily away, replacing it with cold outside air that has been chilled through contact with soil from which radiation had gone on unchecked.

Spraying of trees to afford protection from frost has been attended with some success. However, it is not possible to combat a heavy frost in this way on account of the heavy coating of ice formed, which strips leaves and even large branches from the trees. If the tree is in bloom the water is likely to cause damage by interfering with pollination. These objections do not have so much weight in the case of protection of garden plants, and spraying with water may be very effective where these are concerned.

Good results have been obtained by turning fairly warm irrigation water into fields or orchards on moderately cold nights. This method will not afford protection against damage by heavy frosts. Frequent irrigation of citrus trees during the winter months may start new growth and render the trees much less resistant to cold.

STIRRING THE AIR

The temperature of the air 40 feet above the ground is often from 7° to 10° higher than that 1 foot from the ground. It is obvious that if the air within this distance from the ground could be mixed, a damaging frost would not be likely to occur in most cases. Attempts have been made to do this with large power-driven fans, but it was found that the expense was far too great for the plan to be considered from a practical standpoint.

ADDING HEAT

The third principle of frost protection is concerned with the addition of heat to the lower air to replace that which is lost by radiation and conduction. This is generally accomplished by lighting a large number of small fires throughout the area to be protected. Oil, wood, coal, oil-soaked shavings, tree prunings, and carbon briquets, or a combination of two or more of these fuels is used.

Persons unfamiliar with temperature conditions in the lower air on frosty nights sometimes speak of the fallacy of attempting to "warm up all out-of-doors." It is well known that warm air is less dense and therefore lighter than cold air. This fact is exemplified in many ways in everyday life; the hot gases from a stove or furnace rising through a flue and the lifting power of the old hot-air balloons are good illustrations. As a matter of fact, roughly speaking, the warmed air continues to rise and cool until it reaches a point where it has the same temperature as the air surrounding it. On first thought it might be supposed that the air warmed by fires in orchards or fields would pass upward to a considerable altitude and be replaced by cold air from outside the heated area so rapidly that the effect on the air temperature in the heated area would be very slight.

However, the factor of temperature inversion on frosty nights (the relatively thin layer of cold air near the ground with warmer air overlying it) completely alters the situation, in that the heated air does not rise far before it finds itself surrounded by air of the same temperature as itself. As the hot gases leave the fires, they mix rapidly with the surrounding colder air, so that the resulting temperature of the whole mass is not very high. When the air 40 feet above the ground is 10° warmer than that a foot from the ground, the heat from the fires is nearly all expended in raising the temperature of the air within this 40-foot layer. In other words, the warmer upper air acts as a roof which stops the ascent of the heated air. (See fig. 4.)

It is plain that the degree of temperature inversion near the ground, that is, the rate at which the temperature increases with increase in altitude, determines the thickness of the layer of air that must be warmed to obtain a definite increase in temperature at the ground. If the inversion is strong the surface temperature can be raised several degrees more than when the inversion is slight, the amount of fuel consumed being the same in both instances.

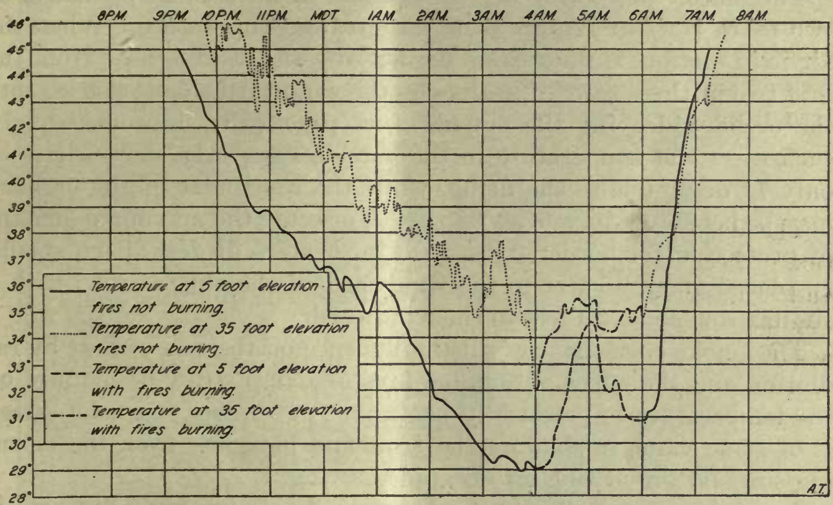


FIG. 4.—Continuous records of the temperature 5 feet and 35 feet above ground on a tower in a pear orchard. Note the large difference in temperature at the two levels before the orchard heaters were lighted at 4 a. m. By 5 a. m. the temperature was practically the same at the two levels, showing that the heat from the burning oil had been nearly all expended in raising the temperature of the air within 35 feet of the ground. This point is further illustrated by the fact that at 5 a. m. when most of the heaters were extinguished, the temperature at the 5-foot level fell rapidly, while it remained practically stationary at the 35-foot level.

The amount of this temperature inversion varies greatly from night to night, and in different localities. It is mainly determined by the amount of fall in temperature from afternoon to early morning. If the afternoon temperature is high and the temperature falls to freezing on the following morning the inversion in temperature is likely to be great.

A large number of small fires will be found to be more efficient in raising the temperature than a small number of large fires, especially in localities where the temperature inversion is relatively slight. The heated gases leave the large fires at a high temperature and tend to rise some distance above the ground, while the gases from a number of small fires are mixed with the surrounding cooler air until the temperature of the whole mass of surface air is raised slightly, although remaining still relatively low.

Another and probably the most important factor in protection by heating is the amount of air movement near the ground. When the air is calm the air warmed by the heaters remains over the fired area and the maximum results in raising the surface temperature are obtained. When the air is in motion, even though it is moving only a few miles per hour, the heat is steadily carried away and a greater quantity of fuel must be consumed to obtain the same effect on the surface temperature.

The matter of reinforcing the borders of an orchard with one or two extra rows of heaters is of the greatest importance. When the air is in motion, if there is no border row of fires, the heat from the first two or three rows of heaters on the windward side is carried into the orchard, leaving the outside rows practically unprotected. In such cases the temperature in the outside rows may show a rise of only 1° or 2° due to the firing, while the remainder of the orchard may be benefitted by a 5° or 6° rise. To secure the maximum amount of protection for border trees, a row of heaters, 10 feet apart, should be placed about 40 feet to the windward of the outside row, with a similar row about 20 feet to the windward.

The smoke cover has very little influence on the loss of heat by radiation and the effect of smudge fires of damp straw or manure on the temperature is practically negligible. However, a smoke screen is of some value in shading the fruit and blossoms from the morning sun and preventing a too rapid thawing.

Smudging and Pollination.—In some deciduous fruit districts it has been asserted that the smoke from the open oil heaters interferes with pollination. However, the experience of a large number of fruit growers, who for many years have smudged their trees while in full bloom, does not bear out this contention. Pollination usually takes place on the day the blossom opens and even if considerable soot is deposited within the flower on the following night, no damage results. As a matter of fact there is seldom enough soot deposited in a blossom to hinder pollination, even when firing is continued for several hours.

During the seasons of 1917 and 1918 Mr. B. B. Lowry, of Medford, Oreg., cooperating with the county pathologist, smudged six pear trees, including practically all varieties grown commercially in the district, every night from the time the buds began to open until the fruit had set, in order to note the effect on pollination. Three open lard-pail heaters were placed almost directly under each tree and the blossoms were coated with soot to an extent that would never be found in actual practice. The experiment was carefully checked by the writer during the 1917 season. All the smudged trees bore heavy crops both years and the yield of near-by trees that were not smudged was not noticeably larger. (See figure 5.)

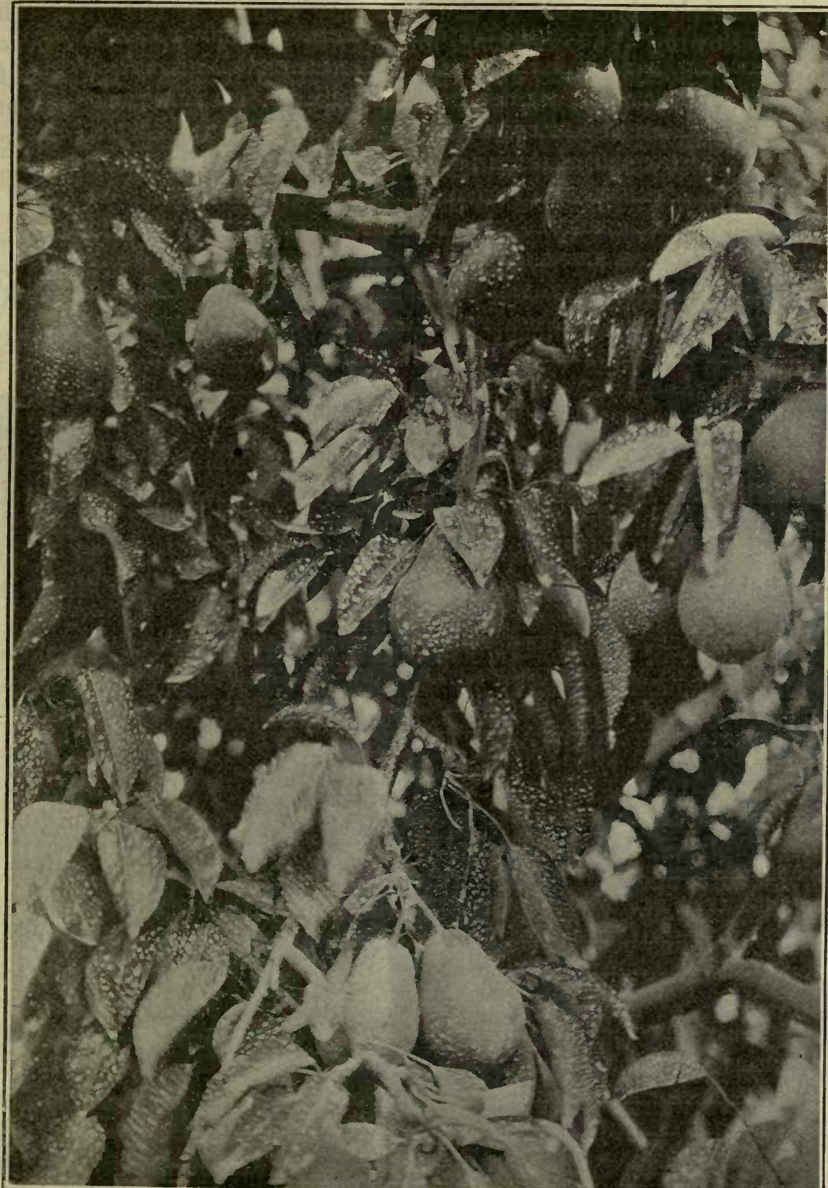


FIG. 5.—Fine crop of perfectly shaped Bartlett pears on tree used in experiments to determine the effect of smudging on pollination. This tree was smudged heavily every night from the time the buds began to open until the fruit had set. Photograph taken soon after spraying.

Statements that bees will not work in blossoms that have been smudged may be due to a lack of understanding of the habits of the bee. It is well known that bees will often not work on even moderately cool days; if the afternoon temperature is below a certain point, namely about 60° F, the bees may remain in the hive. On days following the occurrence of a frost heavy enough to make smudge protection necessary the temperature is likely to be sufficiently low to keep the bees from working to any great extent. On warm sunshiny days following heavy frosts, however, the writer has often observed great numbers of bees working in blossoms that had been heavily smudged on the previous night.

The smoke from the open heaters is very dense and in some localities the residents of towns have objected to orchard heating on account of the resulting dirt. The smoke problem has been partially solved by the development of improved heaters, but no practical heater has yet been devised that will burn under orchard conditions without giving off some smoke. The newer types are rather complicated and are too expensive to be used for the protection of crops that do not bring a large return. There are few commercial fruit districts in the country that do not suffer severely from frost damage at intervals, and in most localities people are willing to put up with some inconvenience from smoke on a few nights a year in order to avoid the business depression likely to follow the loss of a large portion of the crop.

Protection of Olives.—In some parts of California the olive crop is often damaged severely by fall frosts when the fruit is being picked. In some olive-growing communities as much as 70 per cent of the crop has been lost in some seasons in this manner. Many growers have hesitated to resort to orchard heating to save the crop for fear that the oil smoke would affect the flavor of the olives. Mr. F. Mier, of Fair Oaks, Calif., has been protecting his olives with open oil heaters for several years and has never been able to note any effect on the flavor of the fruit. Practically his entire crop has been packed ripe and has always been of the highest quality. It is unlikely that the oil flavor ever penetrates the thick, tough skin of the olive, but even if this were possible, the treatment with lye which the fruit is given to remove the bitter element would undoubtedly remove it.

Relative Value of Different Fuels.—The kind of fuel most suitable for use in a given locality depends on a number of factors. The first consideration is the relative cost of the different fuels. On the Pacific coast oil is used almost exclusively on account of its low cost as compared with coal or wood. In most other parts of the country coal is the cheaper fuel. The acreage protected by wood fires is relatively small. Because of the ease with which it may be lighted and extinguished, handled and stored, oil is to be preferred when its cost compares favorably with that of other fuels.

Fuel oil of from 25 to 28 gravity is the most satisfactory for use in either the lard-pail or improved type of heater. This oil leaves very little residue and burns practically as long as heavier oils.

Types of Oil Heaters.—Up to the present time few deciduous fruit crops have been valuable enough to warrant the use of any but the simplest and cheapest types of heaters for protection against frost. Since good results can be obtained with these heaters (the lard-pail type) when a sufficient number to the acre is used, the only incentive to change to a more complicated type of heater is the abatement of the smoke and soot. The indications are that the smudge does not injure deciduous blossoms or fruit to any measurable degree and its elimination is desirable only on account of the resulting dirt.

The small open lard-pail heaters are not well suited for the protection of citrus fruits because (1) at the time protection is necessary the fruit is almost ready to be picked and even a small deposit of soot is likely to impair its marketing qualities, and (2) protection is necessary in midwinter, when the temperature is likely to remain below the danger point continuously for 10 or 12 hours and heaters of large capacity and long burning time are required.

A 5-quart lard-pail heater will burn about 2½ hours, but as the oil gets low the amount of heat given off is greatly decreased. The 2-gallon lard-pail heater will burn about 4 hours, but little heat is given off after 3½ hours.

The length of time the larger heaters will burn depends altogether on the amount the drafts are open. To combat the long cold periods, that sometimes visit the citrus districts, without refilling during the night, heaters of a capacity of about 7 gallons should be used. These will burn from 8 to 10 hours at near their full rate.

More than a score of more complicated heaters have been developed with the idea of improving combustion and reducing the amount of smoke. These run all the way from the 3 or 4-gallon capacity short-stack heater (fig. 6) to the high-stack heater of from 7 to 20 gallons capacity (fig. 7). The stacks on the smaller heaters are from 4 to 10 inches high, while on the larger heaters they are from 3 to 5 feet high. With one or two exceptions the "down draft" principle is used in all the improved types. Air is admitted through the top of the oil reservoir, causing the oil to burn there and raise the temperature sufficiently to change some of the oil to gas. The gas then passes upward and is burned as it rises through the stack. A supply of air to support combustion is admitted through holes cut in the base of the stack.

In order to burn clean and supply the desired amount of heat the gas must be given some time to burn before its temperature is reduced by mixing with the cold outside air. This is the function of the tall stack. Generally speaking, the high-stack heaters burn with less smoke and soot than any other type in general use. The short-stack heaters throw off less smoke than the lard-pail type, but the amount is large enough to be objectionable.

The high-stack type of heater is open to the objections that the heat is released too far above the ground, at too high a temperature and with too great an upward velocity to obtain the best results. These objections would probably be serious in localities where the temperature inversion is slight, but in southern California, where these heaters are in most general use, the temperature is often 20° higher on a cold night at a height of 200 feet above the ground than at the ground.

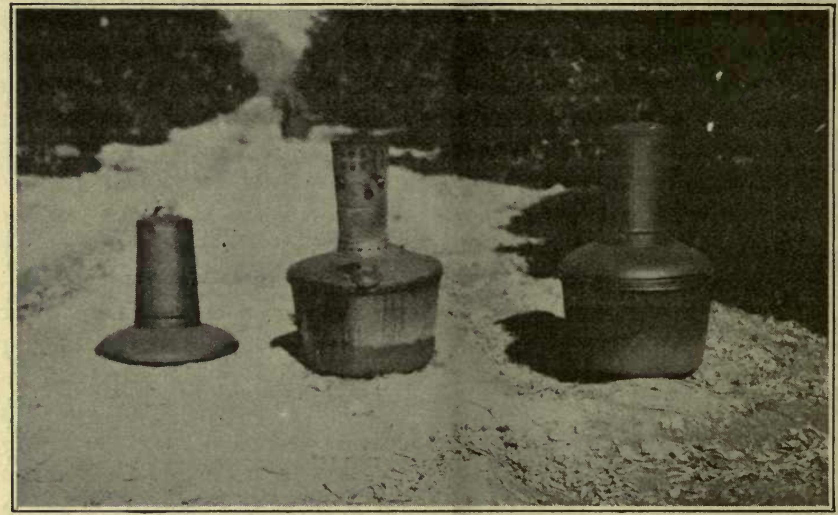


FIG. 6.—Short-stack oil heaters in orange grove. The one on the left has cover removed and draft open. This type of heater has given great satisfaction where there is not too much objection to the formation of heavy smoke.

There is no doubt the heat should be liberated as near the ground as possible in order to obtain the best results. However, at the present time the use of the high stack is the only practicable means of obtaining fairly perfect combustion. Some of the heat from these heaters is undoubtedly lost through its rising too high above the ground, but this is probably nearly offset by the additional heat obtained through the more complete combustion. The smoke and soot given off by other types of heaters are more or less completely consumed in the high-stack heater. It is estimated that from 40 to 50 per cent of the heat in the oil is made available in the lard-pail type, as against 70 to 80 per cent in the high-stack type.

The plan of using small oil heaters which burn slowly and setting them directly under the trees has not met with much success up to the present time. There is always danger of severely injuring the tree if the heater burns too high, and the problem of distributing the heat uniformly throughout the tree has not yet been solved.

Protection by Direct Radiation From Heaters.—Though protection from frost is afforded mainly through raising the temperature of the air by mixing with the hot gases from the heaters, direct

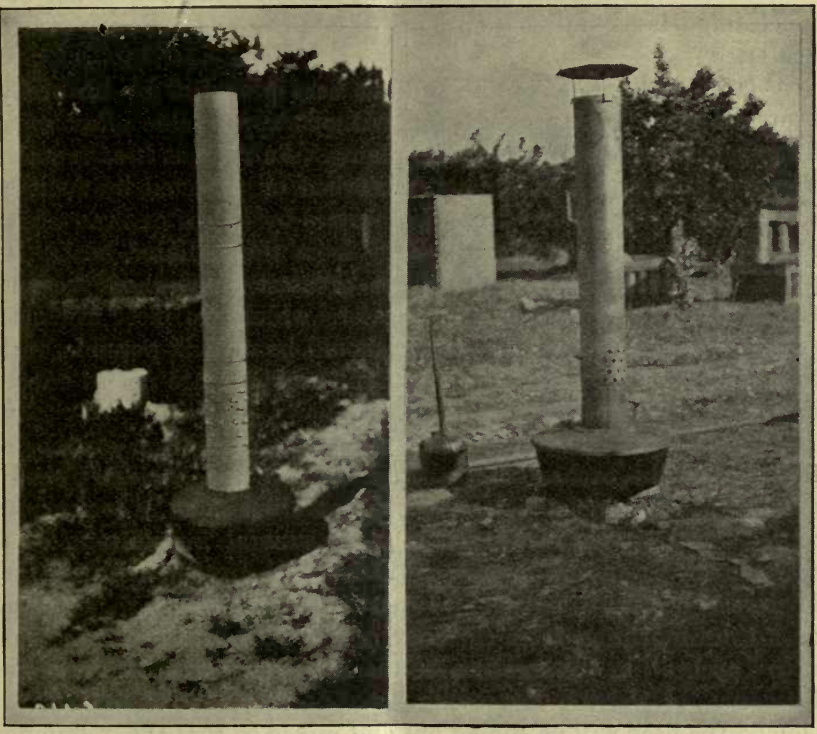


FIG. 7.—Two types of high-stack oil heaters. Air is admitted through a draft opening in the cover of the bowl, supporting combustion at the surface of the oil. The hot gases then burn while rising through the stack, the necessary air being admitted through the perforations near the base. At the left of the heater on the right is shown a lighting torch of the type in most general use. It consists of an ordinary oil can with a long spout, into the end of which is inserted a wick of asbestos wrapped in small mesh wire screen. The lighting fluid is ignited while flowing through and around the wick and falls in flaming drops.

radiation of heat to the plants or trees is important in some cases. This is particularly true when the high-stack heaters are used. When these are burned at a moderate rate at least a portion of the stack is likely to be heated to redness. The heat radiated from the stack to the fruit and foliage serves to counterbalance the loss of heat through outgoing radiation. The amount of radiant heat reaching the tree depends on the distance from the heater. With increasing distance the radiation intercepted decreases very rapidly.

Experiments conducted by Prof. H. H. Kimball show that when the high-stack heater is burning at a moderate rate with only the lower section of stack red-hot, the heat radiated directly to the tree is sufficient to counterbalance outgoing radiation at a distance of 10 feet. When the entire stack is red-hot the outgoing radiation will be counterbalanced at a distance of about 15 feet.

With the short stack and lard-pail heaters radiation is not of so much importance unless the plants to be protected are very near the heater.

A large percentage of the radiant heat given off by an orchard heater is lost directly to the sky without appreciable effect on the temperature of the air or of the plants. As radiant heat travels in straight lines and is completely absorbed or reflected by fruit and leaves, any fruit shaded from the heaters by leaves or branches can receive practically no direct benefit from the radiated heat. It is plain, therefore, that to obtain the greatest amount of protection from the same amount of fuel, heaters which are most efficient in raising the temperature of the air should be used if possible, rather than those which radiate most of their heat and are not so effective in raising the temperature of the air.

Distribution of Heaters.—For the best distribution of the heat throughout the orchard it is better to have the heaters placed in every row, if possible, instead of concentrating them in every fourth or fifth row. This makes for a more general intermixing of the warmed air from the heaters with the cold air surrounding them. If rows of heaters some distance apart are lighted through an orchard on a calm morning, from the edge of the fired area it is possible to note " arches " in the smoke over the fired rows, with depressions in between. If the air is moving steadily from one direction, even slowly, the heat will be spread out and mixed so that this " chimney " effect will not occur, even if rows some distance apart are lighted.

In some parts of southern California, where the air drift is practically always continuous from the same direction during a cold night, firing along " check lines " is practiced. Mr. Willis S. Jones, of Claremont, Calif., is the originator of this plan and has had great success with it on his own 40-acre orange grove. His plan is as follows (see fig. 8):

The air movement in his grove is generally steady and is normally from the north. It sometimes shifts to the northeast and east, but practically never blows from a southerly or westerly direction. On the northern and eastern borders of the grove three short-stack citrus heaters are placed to each tree, and on the line immediately inside these heaters are placed one to a tree. The remainder of the orchard is divided into checks 16 trees square and a double row of heaters is distributed along each check line. The remainder of 3,800 heaters are placed one to each tree in the colder parts of the orchard and one to two trees in the remainder of the orchard.

When the time to fire arrives, the direction of the air drift is noted, and the outside row to windward is fired first so that the heat

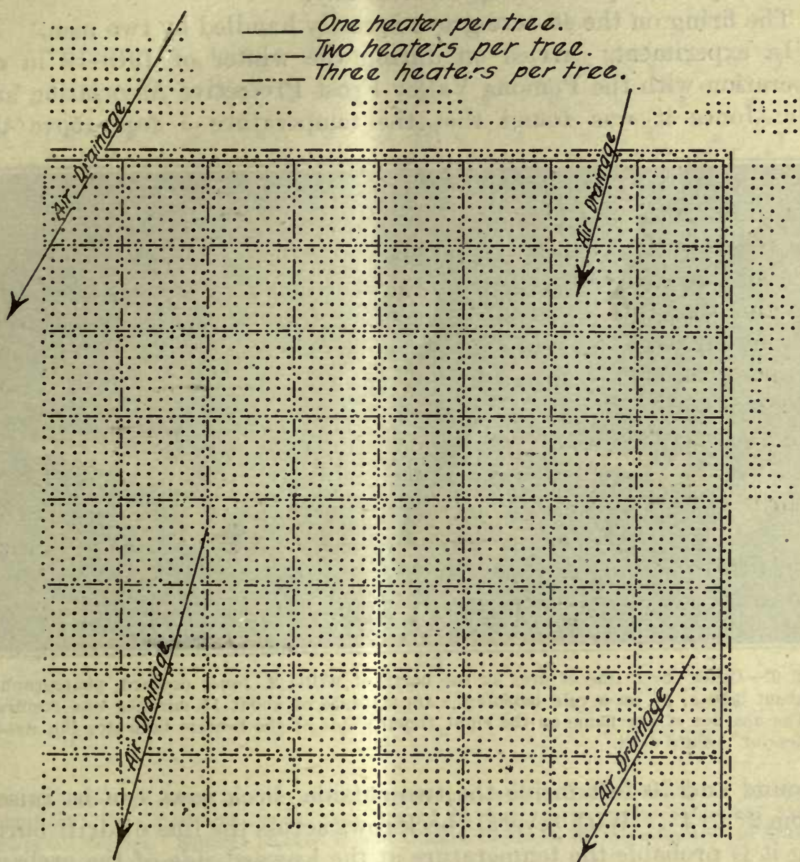


FIG. 8.—Diagram of 40-acre orange grove owned by Willis S. Jones, near Claremont, Calif., illustrating his system of firing orchard heaters along check lines. Dots represent orange trees, spaced 20 feet apart on the square. The normal direction of the air drift on cold nights is shown by the arrows.

is carried into the orchard. (See fig. 9.) Three more east and west lines are fired immediately afterwards, and if the temperature continues to fall, three north and south lines are fired. The 40 acres are then divided into 16 checks of 256 trees each, surrounded on all sides except the extreme west and south by lines of fires 20 feet apart. If the temperature still remains low in the colder parts of the orchard, the eighth rows east and west are fired. This has been necessary on only two occasions in four years. During the four seasons from 1914 to 1917, more than 580 heaters were never lighted at one time on the 40 acres. The heaters are burned at their maximum rate at all times. Mr. Jones advocates this system of firing on account of—

1. Easy and rapid lighting; one man can light 250 to 300 heaters per hour.

2. Easy and rapid refilling the next day.

The firing on the 40-acre grove is easily handled by two men.

In experiments carried on during the winter of 1918–19 in cooperation with the Pomona Valley Frost Protective Association and Mr. Jones it was found that the temperature 5 feet above the

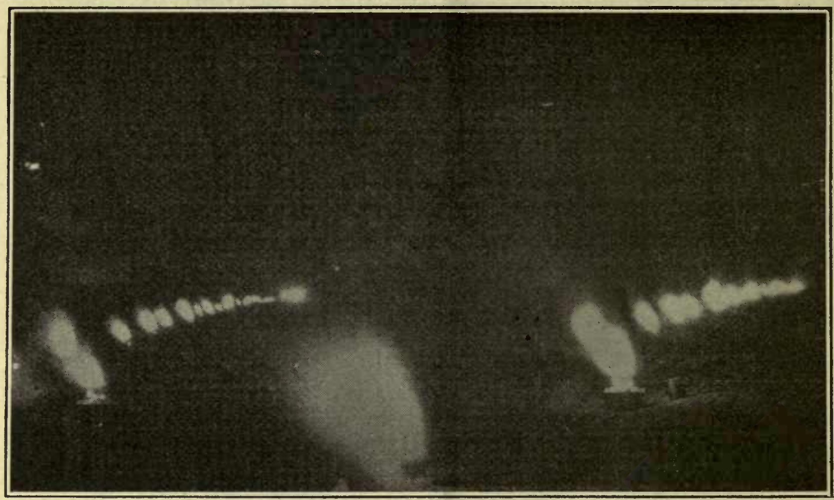


Fig. 9.—Outer check line of fires on the north of Willis S. Jones orchard, photographed about 3.30 a. m. on a cold morning. An exposure of about 15 minutes was required. The absence of any flame on the right (north) side of the heaters indicates the steadiness of the air drift.

ground and 70 feet inside the two outside check rows can be raised from 2° to 4°. With several check rows across the line of drift burning it is probable the temperature at the leeward side of the orchard is raised a somewhat greater amount. In adopting this system of firing, the space between the check lines should contain at least one heater to every two trees for use in an emergency, when the fires on the check lines may fail to hold the temperature above the danger point.

The heated air from a fired orchard often drifts through neighboring orchards which are not fired, affording them in some cases even more protection than the fired orchard itself. (See figs. 10 and 11.)

Number of Heaters per Acre.—The number of heaters to the acre necessary for protection depends on the location of the orchard with regard to surrounding topography. For deciduous orchards in the colder sections there should be not less than 100 of the 5-quart lard-pail heaters to the acre, and if exceptional cold is likely to be experienced frequently, about 140 to the acre should be used. Of course all the heaters are practically never lighted at once; some are always held in reserve to be used when others burn out. In the warmer deciduous fruit regions, where the temperature is not likely to fall below 25° at any time, these heaters should be set about 80 to the acre.

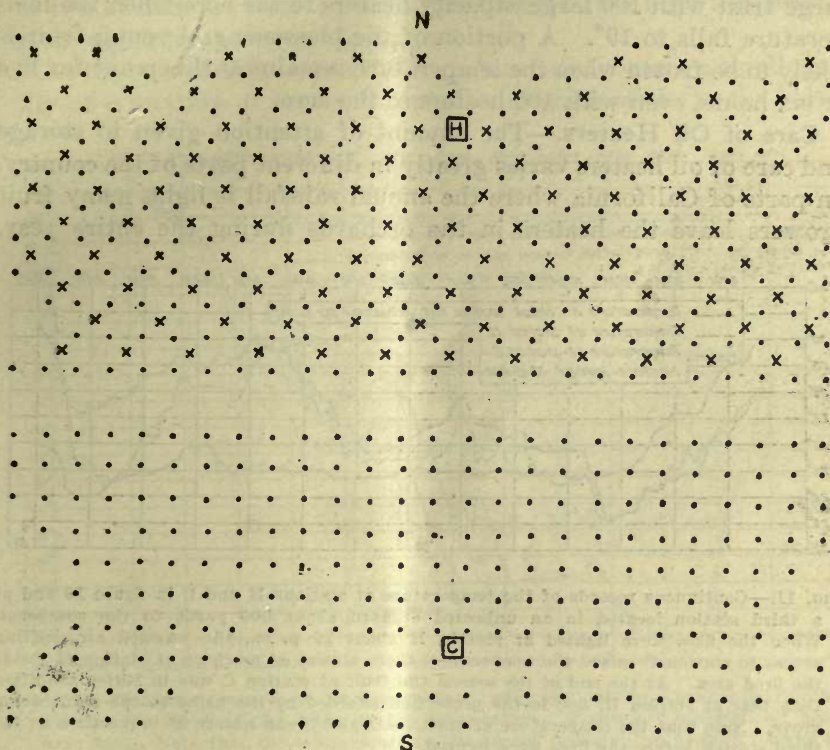


FIG. 10.—Plan of lemon groves where temperature records shown in figure 11 were obtained. Dots represent lemon trees, spaced 20 feet apart; crosses represent high-stack oil heaters. Squares marked H and C show locations of thermometers in heated and unheated groves, respectively.

The number should not be much less if 2-gallon lard-pail heaters are used. The larger heaters have a longer burning time, but the amount of heat released in a given time is not much greater. (See fig. 12.)

The number of the newer improved type of heater necessary for protection depends on the location of the orchard and on the kind of fruit to be protected. Orange groves on low ground, where temperatures as low as 20° may occur as often as every five or six years, should have at least one large capacity heater to each tree. On the higher slopes the number may be reduced to 80 per acre, but if extremely heavy frosts, like those of 1913 in California, are to be fought successfully, dependence should not be placed on a much smaller number. Some growers have successfully protected their orange crops for several years with as few as 30 or 40 heaters to the acre, but no exceptionally heavy frosts occurred during that time. (See figs. 13 and 14.)

Lemons are more susceptible to frost damage than oranges, but where a large acreage is protected it is usually possible to save the large fruit with 100 large capacity heaters to the acre when the temperature falls to 19°. A portion of the blossoms and young fruit is likely to be frozen when the temperature remains at this point for five or six hours, even with 100 heaters to the acre.

Care of Oil Heaters.—The amount of attention given to storage and care of oil heaters varies greatly in different parts of the country. In parts of California where the annual rainfall is light, many fruit growers leave the heaters in the orchards during the entire year,

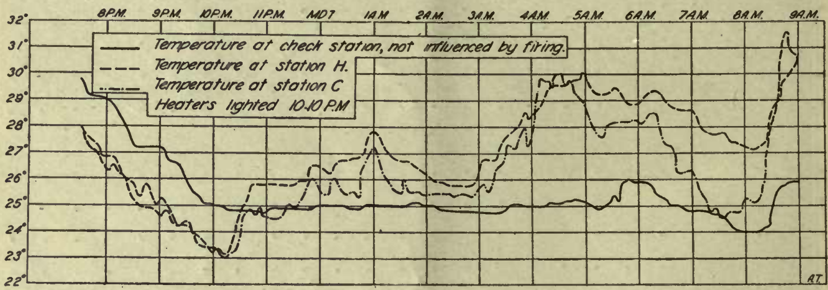


FIG. 11.—Continuous records of the temperature at stations H and C in figure 10 and at a third station located in an unheated orchard about 500 yards to the southeast. When the fires were lighted at station H about 10 p. m., the warmed air drifting across to station C raised the temperature there almost as much as at station H inside the fired area. At the end of the season the fruit at station C was in better condition than that at station H, due to the protection afforded by the firing in the neighboring grove. Note that the temperature at stations H and C ran nearly 2° lower than at the third station before the fires were lighted.

setting them up close to the trunks of the trees after the danger of frost is past. Trees are sometimes injured or even killed through oil from leaky heaters penetrating the soil around the roots. For this reason, heaters left in the orchard should be emptied at the end of the season. Lard-pail heaters are usually covered with a film of oil, which helps to prevent rusting, and the rate of deterioration is little, if any, greater than is the case when they are stored under cover. Where there is considerable annual rainfall, lard-pail heaters should be emptied, dipped in heavy oil, and stored under cover when not in use. With ordinary care heaters of this type will last 10 years or longer. Several orchardists have used them 14 and even 16 years without losing more than a small percentage through deterioration. Some fruit growers prevent contact between the bottoms of the heaters and the ground by placing the heaters on small square pieces of board.

The cost of the larger heaters is so great that it is good practice to give each one a coat of good stack paint at intervals of 2 or 3 years to prolong its life. Mr. Willis S. Jones, of Claremont, Calif., has his heaters thoroughly brushed with a steel brush to remove rust and dirt. Each heater is then placed on an iron grating under which one or two heaters are burning until it is brought to a high temperature, after which the paint is applied hot.

At the end of each season the heaters usually contain a small quantity of a mixture of soot and asphaltum, which sticks to the bottom

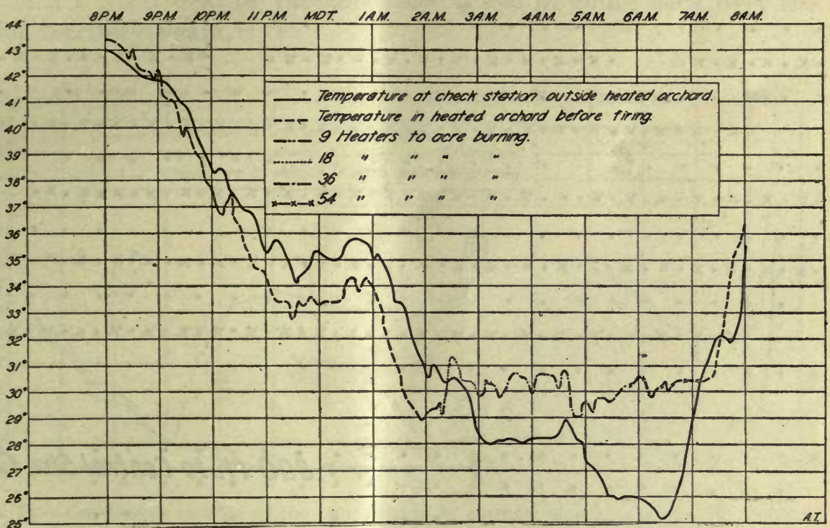


FIG. 12.—Continuous records of the temperature inside and outside a heated pear orchard, showing the effect of the firing on the temperature. Five-quart lard-pail oil heaters were used. Note that the temperature in the heated orchard ran about 2° lower than at the check station before the heaters were lighted.

and is difficult to remove when cold. The usual method of removing this material has been to burn it out with distillate. In doing this accidents often occur and piles of several hundred or more heaters sometimes catch fire, ruining the heaters and endangering surrounding property.

At the Bear Creek Orchard, Medford, Oreg., the manager, Mr. B. B. Lowry, has a trench covered with sheet iron on which he treats the empty heaters at the end of the season. A fire is built under the iron, using the residue from the heaters for fuel, which burns fiercely. A large inclined flue carries away the smoke from the fire and creates a draft. The heaters, a dozen at a time, are placed on the sheet iron until they become hot and the residue is loosened, when they are removed with tongs one by one and rapped against a post, causing the residue to fall out. They are then examined for leaks by holding them upward toward the sun. The work can be handled very rapidly in this way and there is little danger of accident.

Coal Heaters.—Coal is burned in open piles on the ground, in wire baskets and in specially designed sheet-iron heaters. Coal heaters possess some advantages over oil heaters in that the heat can be applied near the ground, there is no strong up-draft and usually not much soot or smoke after the first few minutes of burning. On the other hand, coal fires are often difficult to light and hard to regulate; the fires often have a tendency to smolder slowly or burn out

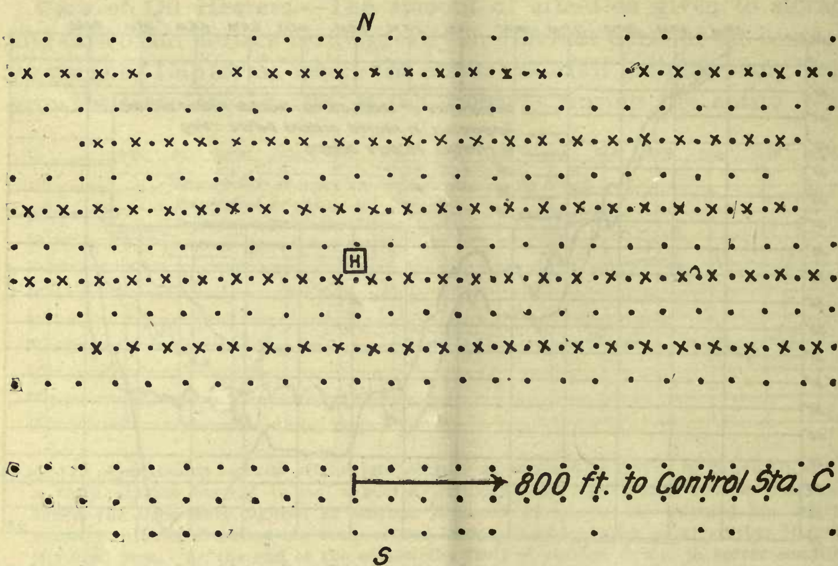


Fig. 13.—Plan of orange grove where temperature records shown in figure 14 were obtained. Dots represent orange trees spaced 20 feet apart; crosses represent low-stack oil heaters. The square marked H shows location of thermometers in fired orchard. The check station was located about 800 feet to the eastward to avoid the influence of the fires. The air drift on cold nights was normally from a northerly direction.

with a rush. When firing is required for several hours it is necessary to replenish the fuel in the heaters. The labor costs are relatively high, as a large number of men are required to attend to this work. In California reserve supplies of coal for each heater are kept in wooden boxes set under the trees. At the end of the season the heaters are placed on top of these boxes and are left out all the year.

The number of coal fires to the acre should be about the same as when the lard-pail oil heaters are used.

Lighting Equipment.—Orchard heaters of all kinds can be lighted easily and rapidly with torches burning a mixture of gasoline and distillate or gasoline and fuel oil. (See fig. 7.) These torches drop the burning liquid into the heaters, starting combustion immediately. Lard-pail heaters when new are sometimes difficult to light. If the burning liquid from the torch is poured in a ring on the edge of the heater, no difficulty will be experienced. After three or four firings the carbon deposited on the rim of the heater acts as a wick and a little burning liquid dropped anywhere in the oil will ignite it readily.

Many fruit-growers hire school boys to light the heaters and have been able to place great dependence on them.

Coal fires should be carefully built up with oil-soaked waste or paper and a small amount of kindling. If a portion of the fires fail to burn a great deal of valuable time is lost in going back over the same territory again.

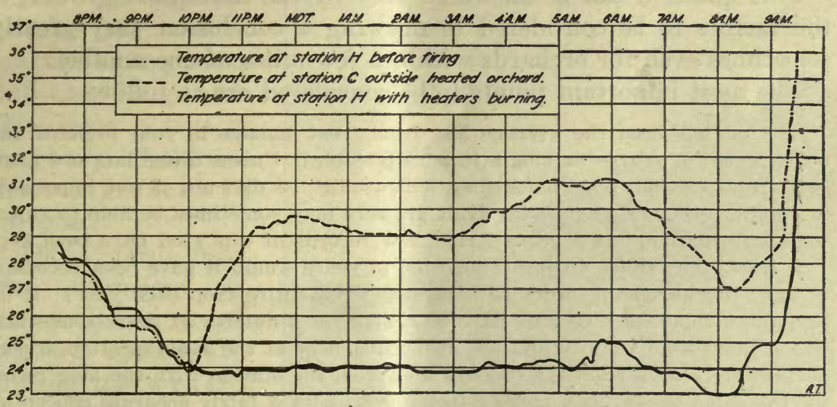


Fig. 14.—Continuous records of the temperature at stations shown in figure 13, showing the effect of firing on the temperature. Low-stack oil heaters of the type shown in figure 6 were used.

Storage of Fuel.—In order to carry on orchard heating successfully it is necessary to have enough fuel within reach to last through the longest cold spell likely to be experienced. Too many instances have been noted where the crop has been protected successfully through several cold nights at considerable expense, only to be lost on one cold night on account of lack of fuel. Where orchard heating is practiced by many growers in a community it is a good plan to buy and store large quantities of fuel oil on a cooperative basis, as is done in southern California. Orchards located near the storage tanks can haul directly from them, but in the case of those located a mile or more distant, storage tanks should be provided in the orchard.

The necessity of pumping oil from storage tanks should be avoided by raising the tanks high enough above the ground so that the oil will flow into the wagon tanks by gravity. Where the ground is not too flat, the storage tank can be so located that the oil can be put into it and taken out by gravity. If more than 5 acres are to be fired with oil a portable tank from which to fill the heaters is almost a necessity on account of the saving in time and labor. Three men with a tank wagon can fill heaters very rapidly, one man driving and two men drawing oil into 5-gallon buckets and pouring it into the heaters, filling two rows at the same time. The owners of two adjoining orchards often use the same tank wagon.

Owners of small orchards often handle the oil in metal drums of about 50 gallons capacity. The heaters are filled directly from the drums, which are hauled through the orchard on sleds.

IS ORCHARD HEATING PROFITABLE?

This question can be answered only by the individual grower, as the factors to be considered in drawing a conclusion vary greatly, sometimes even for orchards within a few miles of one another. The most important points to be considered are as follows:

1. What has been the average loss from frost damage in your orchard during a period of years—as long a time as possible? Unless these data are available from personal experience they will usually be difficult, if not impossible, to obtain, although neighboring fruit growers may sometimes be able to supply some information. As a general rule, few records of this kind have been kept.
2. How many times during this period of years would it have been necessary to light the heaters in order to have saved the entire crop each year? If dependable temperature records have been kept for a number of years somewhere in the immediate vicinity and are still being kept at the same location, a comparison of records from the orchard and from the station with the long record for the same season may make it possible to gain a fairly accurate conception of what temperatures have been experienced at the orchard in question.
3. Will the value of the fruit lost through frost damage more than pay interest and depreciation charges on an investment for all necessary heating equipment, together with all costs of operation?
4. Is your locality likely to be visited by short periods of extremely cold weather during the growing season that may badly injure or kill the trees? This question can probably be determined from Weather Bureau records from some station in the vicinity.

There are two conditions under which orchard heating will not be profitable. The orchard may be located where frost damage is too slight in the long run to pay the expenses of heating, or the orchard may be in an exceptionally cold section where damaging frosts occur so often that the costs of protection are too great to be borne by the crops.

The number of cases of the first-mentioned type is smaller than would appear at first thought. The saving of one season's crop, which would otherwise have been a total loss, will justify the expense of heating for a good many years. Some practical growers consider it good business policy to have frost-fighting equipment, even though it is necessary to use it only one season out of five.

In cases of the second type it is obvious that the frost hazard is so great that fruit growing will not be profitable in the long run and the trees will eventually have to be removed.

The statement is often made that the policy of growing fruit on the colder low ground is wrong and that orchards should be confined to the higher and more frost-free locations. This is not always true. In some parts of southern California the difference in the cost of irrigation more than makes up for the expense of protecting the orchards on the lower ground from frost. In addition to this the cost of cultivating steep hillsides is greater. The same is true of certain deciduous fruit districts in Oregon.

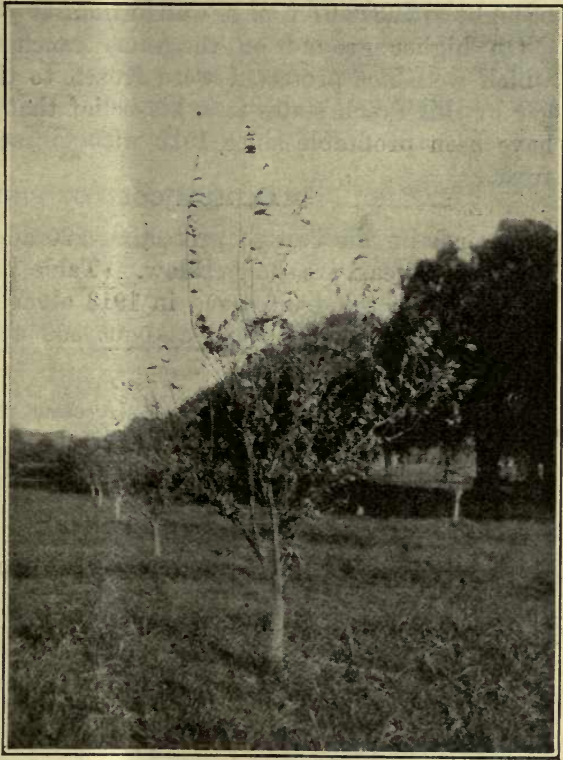


Fig. 15.—Young lemon tree almost entirely stripped of foliage by frost. The fruit was a total loss and most of the the remaining leaves dropped later.

On a farm near San Francisco potatoes have been grown successfully during the winter months for several years with the aid of open lard-pail oil heaters. Irrigation water necessary for crops grown during the summer is scarce and expensive, while the rainfall during the winter months is ample. The new crop is harvested in the spring, and reaches the market so early that exceptionally good prices are obtained.

The degree of success attained in protecting potatoes at this place indicates that low-lying crops may be protected against ordinary spring frosts by using the small open lard-pail heaters, set from 60 to 80 to the acre. In addition to the heating of the air over the plants, the direct radiation of heat from the heaters aids considerably in protecting the plants immediately surrounding them. In planting a field to a low-growing crop that is to be protected with heaters, vacant spaces about 18 inches square should be left at the points where the heaters are to be placed, as the plants very close to the heaters are likely to be scorched.

Orchard heating has been practiced for six years on one of the largest lemon groves in the country, located in southern California. During the season of 1912–13, a season when the citrus crop in many parts of southern California was practically a total loss and thousands of trees were killed outright, the lemon crop from this grove brought $734,318.07 f. o. b. California.

On higher ground on the same ranch 5-year-old lemon trees which were not protected were frozen to the ground. The manager of this ranch states it is his belief that the business would not have been profitable since 1912 without means of protection from frost.

MAXIMUM COST OF FIRING

Records on the cost of protecting 220 acres on this place during the past six years are shown below. (Table 1.) It will be seen that the returns from the fruit saved in 1913 alone would pay the costs of protection for many years. About 500 acres of lemons are now being protected here.

TABLE 1.—*Average cost per acre for protecting 220 acres of lemons with oil heaters.*[1]

	Year.						Total 6-year average, per acre.
	1913	1914	1915	1916	1917	1918	
Labor, man and horse, filling and lighting pots, per acre	$45.70	$10.55	$10.65	$21.45	$20.60	$22.15	$21.85
Oil	38.35	12.70	4.20	23.20	26.15	17.75	19.55
Depreciation	19.30	19.10	17.40	15.60	14.30	13.00	16.45
Interest	17.85	17.45	15.50	13.40	13.45	11.25	14.80
Upkeep	11.55	7.95	7.65	1.10	5.65	3.70	6.25
Total	132.75	67.75	55.40	74.75	80.15	67.85	78.90
Number of times fired	19	2	7	20	27	21	

[1] Small open heaters used in 1913; down-draft, short stack type in later seasons.

This ranch is located on both high and low ground, but only the low ground is protected. Lemons are more easily damaged than oranges, and as the small green fruit is protected here, the fires are lighted oftener than in most other orchards. The costs given above are for firing about the maximum number of times that would be necessary anywhere in the country.

AVERAGE COST OF FIRING

Mr. Willis S. Jones, of Claremont, Calif., has kept accurate records on the cost of firing his 40-acre orange grove, which is on rather high ground and is fired only a few nights each year as a general rule. These cost figures, given below (Table 2), are for firing a number of times per year which is probably slightly below the average.

It is impossible to estimate present-day costs of equipping an orchard from any of the above figures on account of the increase in the price of all materials used in the manufacture of heaters and other equipment.

Mr. Jones's orchard was not equipped with heaters in 1913 and his crop was a total loss. At the prices prevailing at that time he estimates he lost fully $10,000 worth of fruit in the two seasons prior to 1913, and $25,000 worth of fruit in 1913. In addition, so many of his trees were severely damaged that he experienced a heavy loss in reduced crops during the next several years. Since putting in heating equipment, including the severe season of 1918–19, his losses from frost damage have been negligible.

TABLE 2.—*Detailed costs of protecting 40 acres of oranges with oil heaters.*

EQUIPMENT INSTALLED NOVEMBER AND DECEMBER, 1913.

Storage:		
21,000-gallon galvanized iron tank	$298. 90	
Concrete foundation	45. 92	
Pipe line	164. 46	
Laying pipe line	7. 85	
		$517. 13
Distributing system:		
Wagon	51. 50	
Two 575-gallon tanks, complete	161. 70	
4 buckets	6. 20	
1 dozen lighting torches	9. 00	
		228. 40
Heaters:		
3,800 heaters at $0.58	2, 204. 00	
Painting heaters at $0.02	76. 00	
		2, 280. 00
Thermometers	42. 00	
		42. 00
Total investment		3, 067. 00

OPERATING EXPENSES.

Interest:			
6 per cent on $3,067, original cost			$182. 85
Depreciation:			
Storage tank, 5 per cent on $298.90	$14. 93		
Pipe line, 3 per cent on $164.46	4. 93		
Wagon, 10 per cent on $51.15	5. 15		
Wagon tanks, 8 per cent on $161.70	12. 93		
Buckets and torches, 20 per cent on $15.20	3. 04		
Heaters, 12½ per cent on $2,204	275. 50		
Thermometers, 5 per cent on $42	2. 10		
			318. 58
Operation:			
Oil, 1913, 25,095 gallons at $0.03	752. 85		
Hauling, at $1.50 per 1,000	37. 63		
		$790. 48	

TABLE 2.—*Detailed costs of protecting 40 acres of oranges with oil heaters*—Con.

OPERATING EXPENSES—Continued.

Operation—Continued.			
Oil, 1914, 13,725 gallons at $0.03	$401.75		
Hauling, at $1.50 per 1,000	20.58		
		$422.33	
Oil, 1915, 575 gallons at $0.03	17.25		
Hauling, at $1.50 per 1,000	.75		
		18.00	
Oil, 1916, 15,525 gallons at $0.04	621.00		
Hauling, at $1.50 per 1,000	23.28		
		644.28	
Total for four years		1,875.09	
Credit oil on hand, 17,173 gallons, at $0.04	686.92		
Hauling, at $1.50 per 1,000	25.75		
		712.67	
Net cost, 4 years		1,162.42	
Average cost per year			$290.60
Distributing, filling, firing, taking in, cleaning, and painting heaters:			
1913–14		199.88	
1914–15		204.63	
1915–16		340.90	
1916–17		336.70	
Total cost for four years		1,082.11	
Average cost per year			270.52
Total annual cost for 40 acres			1,062.55
Average annual cost per acre			26.56

Detailed average annual cost per acre.

Interest	$4.57	
Depreciation	7.96	
Operation:		
Fuel	7.26	
Labor	6.76	
		$26.55

BEST METHODS OF HANDLING ORCHARD HEATING

The fact can not be emphasized too strongly that if orchard heating is to be practiced successfully, it must be handled with as much care and attention as spraying, fumigating, or any other necessary farm work. The secret of success will be found in adequate equipment, good judgment, attention to detail, and extreme vigilance. An inadequate number of fires to the acre may often be worse than none at all, as the costs of firing may have to be added to the loss of the crop.

Whenever the temperature approaches the danger point the thermometer *in the orchard* should be watched closely and, if possible, the rate at which the temperature is falling should be determined. If the temperature is falling rapidly the firing must be begun early if the heaters are to be all lighted before the danger point is reached. With a little practice it is often possible to tell with considerable accuracy by inspection of the fruit or blossoms, when the danger point has been reached, regardless of the temperature.

When small apples or pears commence to freeze minute blisters will begin to form on the skin. By keeping constantly on the watch for the first appearance of these blisters on the fruit in the coldest part of the orchard, the firing can be begun at exactly the right time; no fruit will be lost and no oil wasted. By carefully cutting the blossoms of deciduous fruit it is generally possible to note with ice crystals first begin to form in them, and thus regulate the beginning of firing.

When oranges begin to freeze, the section of the skin exposed to the sky takes on a transparent appearance, generally known as the "water-mark," probably caused by the water in the rind freezing and leaving the oil separated. On the following day these oranges can be picked out easily and are called "shiners." By timing the firing with the first appearance of the "water-mark" in the orchard, it is possible to save the fruit and yet prevent waste of oil. Some experience is necessary before the fruit grower is able to use these methods of timing the firing; but the importance of saving oil is well worth giving the matter close attention.

If the small lard-pail heaters are set 100 to the acre, alternate heaters in every fourth row should be lighted first, followed immediately by alternate heaters in every second row if the temperature has been falling rapidly. The effect on the temperature should then be noted and decision made as to whether additional firing is necessary at that time. As soon as a row of heaters begins to burn low, reserve heaters should be lighted, as the amount of heat given off during the last half hour of burning is small.

If the large capacity down-draft heaters are used, all may be lighted at once if desired and the consumption of oil regulated by manipulating the drafts.

During a cold night an isolated cloud passing overhead, by cutting off radiation and to a certain extent reflecting radiation from the earth, may cause the temperature to rise. As the cloud drifts toward the horizon the temperature falls again. Likewise, sudden temporary rises in temperature are caused by gusts of wind of short duration which mix the upper and the surface air. As a general rule the temperature falls rapidly after the wind or cloud has passed and cases are on record where entire crops were lost through extinguishing the heaters at such a time. If clouds are overspreading the whole sky or a sudden rise in temperature due to wind occurs just before sunrise, the heaters may be extinguished, but if the sky remains clear and sunrise is an hour or more away, the temperature should be watched closely during the remainder of the night.

Although it is sometimes difficult to find time to keep records on heating operations during the rush of firing, it should be done whenever possible. The temperature when firing is begun, time of initial firing and number of heaters fired, time of firing additional heaters, the lowest temperature recorded during the night, can all be jotted down from time to time as the work goes on. On the following day an estimate can be made of the amount of oil consumed and the extent of the damage to the fruit, if any. Records of this kind will be found to be of great value in regulating later firing; the more information of this kind gathered, the more efficiently can the firing be handled. Records of this kind will also help to determine whether protection is profitable or not, a question which every grower should solve for himself at the earliest possible time.

If orchard heating is carried on in a careful, painstaking manner, with ample equipment, there are probably few commercial fruit-growing districts where the heaviest frost likely to be experienced can not be successfully fought with orchard heaters.

FROST AND MINIMUM TEMPERATURE FORECASTS

General forecasts of frost for large areas are issued by the Weather Bureau during the growing season, and in certain rather small districts where protection against frost damage is practiced on a large scale, forecasts of the minimum temperature to be expected from night to night are issued. Farmers or fruitgrowers who have a means of protecting their crops should arrange with the nearest Weather Bureau station to obtain forecasts of the kind available in their community.

INJURIOUS TEMPERATURES

So many factors must be taken into consideration in determining whether a given temperature will cause damage that the matter is one of great complexity. The length of time the low temperature persists, the vigor and stage of advancement of the plant, the kind of weather preceding the frost, and the rate of thawing all have considerable influence on the amount of damage that will be done. Other conditions being the same, a weak, undernourished plant will show more injury than a strong healthy one after both have been subjected to the same low temperature.

Pure water has a higher freezing point than water carrying foreign substances in solution. For example, the freezing point of a strong solution of common salt may be 23° or lower, depending on the concentration; the weaker the solution the higher the freezing point. When the weather is warm and sunshine and moisture plentiful, plants make a rapid growth and the sap is likely to be watery and its freezing point high. For this reason a frost which follows a period of weather favorable for rapid growth will cause more damage than the same frost following a period of cold cloudy weather and consequent slow growth.

When a plant freezes a portion of the cell sap is withdrawn from the plant cells, gathering in the intercellular spaces in the form of ice. If thawing takes place gradually and the cell walls have not been ruptured, this moisture is again taken up by the cells as it is melted, without serious damage. If thawing takes place rapidly, however, the intercellular ice is liquefied faster than it can be absorbed by the cells; a part of it is lost by evaporation and the cells are broken down. When fruit crops are damaged by frost the greatest damage is often found on the portion of the tree where the morning sun strikes first. When clouds gather on the eastern horizon before sunrise and obscure the sun for a few hours in the morning after a cold night, damage to vegetation is likely to be slight, provided the temperature does not fall much below the critical temperature. Heavy smoke from orchard heaters or smudge fires may also lessen damage from frost through causing a slow thawing. Of course, if the temperature falls sufficiently low a great deal of damage may be done even when the rate of thawing is slow; in other words, the prevention of a rapid rise in temperature in the morning may often not be sufficient in itself to prevent injury.

It is possible that some of the protection from frost damage obtained by irrigating is due to making available to the damaged plant cells a larger supply of water through increased flow of sap, to replace that lost through freezing.

INFLUENCE OF HUMIDITY ON RATE OF FREEZING

Fruit growers in nearly all sections are convinced that with the same temperature the amount of damage by frost will be greater when the humidity is low than when it is high. Recent studies by I. G. McBeth, of the Leffingwell Rancho at Whittier, Calif., indicate that under certain conditions citrus fruits will be damaged in a shorter time when the humidity is high than when it is low, the temperature being the same in both instances. It was thought this was due to greater conductivity of moist air, the heat being conducted away from the fruit more rapidly, causing the temperature of the fruit to fall more nearly at the rate at which the temperature of the air was falling.

However, in making these investigations allowance was not made for the influences of radiation and the liberation of heat by condensation. Under orchard conditions, blossoms and leaves exposed to the sky lose their heat rapidly by radiation and their temperature may fall several degrees below that of the surrounding air. The temperature of mature citrus fruits falls more slowly than that of the surrounding air but the rate of fall follows more closely that of the outside air when radiation is rapid than when it is slow. Growers of citrus fruits are familiar with the fact that the first fruit to be damaged is that which is exposed to the sky; fruit on the interior of the tree and screened from the sky by leaves or branches often will show no injury with air temperatures several degrees lower. Radiation goes on more rapidly when the air is relatively dry than when it is moist and the temperature of the fruit is likely to follow more nearly that of the surrounding air when the humidity is low.

On nights when the humidity is high, considerable ice is deposited on the fruit or blossoms. When this moisture condenses and freezes, some of the latent heat liberated tends to retard the rate of fall in temperature of the fruit. After sunrise the thawing of the ice and evaporation of the resulting water retard the thawing to a slight extent and this has a tendency to lessen the damage.

It is possible that under actual orchard conditions, these influences which tend to lessen the amount of damage on a night with relatively high humidity more than counteract the influence of the increased conductivity of the moist air.

DECIDUOUS FRUITS

Damage by frost to deciduous fruits usually takes place in the spring when the trees are in bud or blossom or shortly after the fruit has set. The stage of advancement is of the greatest importance in estimating resistance to low temperature; the same degree of frost that causes little or no damage to fruit in bud, may injure the greater portion of the crop two or three days later.

In the case of most deciduous fruits, the same temperature will cause far more permanent damage after the fruit has set than during the period when the trees are in full bloom, and the later the frost after the fruit has set, the greater is the actual loss. This is due to the fact that there is nearly always a great overproduction of bloom and usually from 50 to 90 per cent of the blossoms can be killed without materially reducing the final crop of fruit. This fact often causes orchardists to overestimate the amount of damage to their crops early in the season. One or two uninjured blossoms in each cluster are usually enough for a good crop. With some small fruits and nuts a larger percentage of the blossoms must mature in order to obtain a full crop and damage during full bloom is more serious.

Another point to be considered is the fact that the blossoms do not all open at once; there are often unopened buds and small fruits on the trees at the same time. Even though a heavy frost at this stage may kill all or most of the more advanced blossoms, there may still be a sufficient number of unopened buds left to insure a crop of nearly normal size. However, fruit from late bloom is usually undersized and of poor quality.

In the process of natural thinning the number of fruits on the trees is steadily and rapidly reduced after the period of full bloom and the loss of a large percentage of the fruit retained on the tree at this time is likely to reduce seriously the size of the crop harvested.

It is obvious from the above that the greatest need for protection comes after the period of full bloom. While a single night's frost during the period of full bloom may not seriously reduce the size of the final crop of apples, peaches, apricots, or pears, when the amount of bloom is reasonably heavy, each one of a series of heavy frosts at this period may kill a certain portion of the remaining uninjured blossoms, until not enough sound blossoms are left to make a full crop. Where an orchard is equipped with heating devices the only safe policy is to hold the temperature high enough at all times so that only a few blossoms will be injured.

Apples and pears are often badly injured by frost but remain on the trees and mature. Such fruits are mis-shapen and more or less seedless and are not marketable as first grade. Frosted pears enlarge abnormally near the stem and lose their characteristic pear shape, while injured apples become rough and their shape irregular. Injured fruit of this kind often remains on the trees until a month before maturity and then drops.

The blackening of the centers of blossoms or of small apples and pears does not necessarily mean that they will not mature, though the chances are greatly in favor of their dropping before the end of the season. The injured tissue is often gradually absorbed until the blackening entirely disappears.

Different varieties of the same fruit often differ considerably in degree of resistance to frost damage and when the same critical temperature is given for all varieties, it is applicable only in a very general way. The best possible arrangement to be followed by the orchardist who protects his orchard is to keep in touch with the local county agricultural agent or horticultural commissioner as the season progresses and obtain opinions from him from time to time as to the temperatures that will cause damage. These officials are likely to have had considerable experience in noting the effect of low temperature in the local district and are also familiar with the condition of the fruit or blossoms as they have been affected by previous weather conditions.

It will pay the individual grower to keep careful records of the temperature in his orchard on cold nights, together with notes on the effect on the size of the final crop. After a few seasons, he will have collected enough data to enable him to know with considerable accuracy how low it is safe to allow the temperature to fall before lighting the heaters.

The following table of critical temperatures as recorded by a well exposed thermometer in the orchard is meant to give a general idea of what the blossoms will endure for a half hour or less without injury.

Temperatures endured by blossoms for 30 minutes or less.

Fruit.	Closed but showing color.	Full bloom.	After fruit has set.
	°F.	°F.	°F.
Apples	25	28	29
Peaches	25	26	28
Cherries	25	28	30
Pears	[1] 25	28	30
Plums	25	28	30
Apricots	25	27	30
Prunes	28	29	30
Almonds	26	27	30
Grapes	30	31	31

[1] Bosc 27.

CITRUS FRUITS.

Owing to the lateness of the blossoming period of most varieties of oranges, the fruit has practically reached maturity before the frost season arrives in the subtropical sections where they are grown commercially. In this case, therefore, we have to deal with the chilling of a relatively large bulk in comparison with deciduous fruit or blossoms.

The thick pithy rind of the orange is a poor conductor of heat and the protection it affords causes the temperature of the interior to fall much more slowly than the temperature of the outside air. When the air temperature is falling rapidly the interior of the fruit may be as much as 7° warmer than the air surrounding it, and the temperature inside the fruit lags from an hour to an hour and a half behind the temperature of the air. As the freezing point of orange juice is about 28° F., the temperature inside the fruit will not fall much below this point until the fruit is frozen. (See fig. 16.) It is characteristic of any liquid that in the freezing process sufficient latent heat is given off to maintain the temperature at the freezing point of the liquid until the whole quantity of liquid has been frozen.

Radiation is of great importance in damaging citrus fruit and the fruit exposed to the sky is always the first to be frozen. It is probable that any beneficial effects that may be obtained by covering an orchard or tree are due in a large degree to diminishing the rate of radiation from the fruit so that the fall in temperature inside the fruit lags considerably behind that of the air.

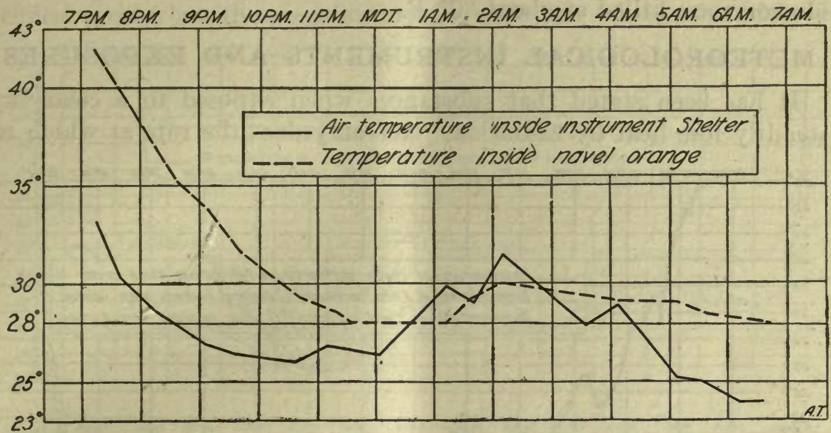


Fig. 16.—Eye readings of the temperature inside a 3½-inch mature navel orange on the tree exposed to the sky, compared with simultaneous readings of the air temperature inside a standard thermometer shelter at the same height above the ground. Note that the temperature inside the fruit did not fall below 28°, which is approximately the freezing point of the juice.

The critical temperature for nearly ripe oranges is most often given as 26° F. to 27° F. During the winter of 1918–19, however, two navel orange groves in southern California experienced air temperatures on different nights as shown in figure 17.

Comparative figures on the amount of damage in the two groves are given below:

Comparison of damage to two groves.

	Grove No. 1.		Grove No. 2.	
	Pounds.	Per cent.	Pounds.	Per cent.
Total fruit harvested	190,975	....	188,230	....
Extra choice	123,075	64	86,800	46
Choice	58,585	31	35,935	19
Partly frozen [1]	0	0	55,170	29
Culls (all sources)[2]	9,315	5	10,325	6
Eliminated (frozen fruit)[3]	0	0	5,400	3

[1] Fruit with up to 15 per cent of tissue 15 per cent frozen marketed in this grade, which brought from 40 to 70 per cent of the price received for undamaged fruit.
[2] Includes misshapen fruit, frozen fruit, etc., total loss.
[3] More than 15 per cent of tissue 15 per cent frozen. This fruit is a total loss.

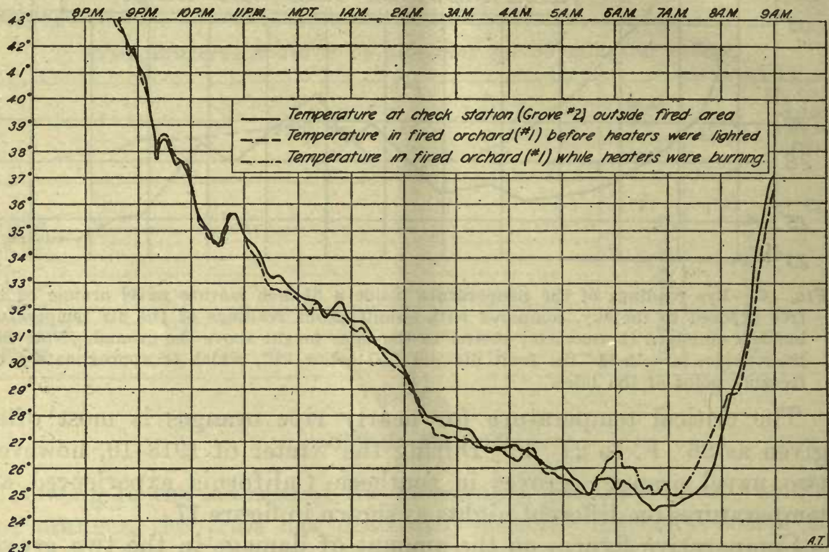
The fruit in grove No. 2 was of a much better quality before the first frost than that in grove No. 1, which accounts for the large amount of culls, not frozen, in grove No. 1. If there had been no damage from frost the amount of fruit marketed as "extra choice" and "choice" would have been much larger in grove No. 2 than in grove No. 1.

Green oranges are injured at considerably higher temperatures, their critical temperature being between 28° F. and 29° F.

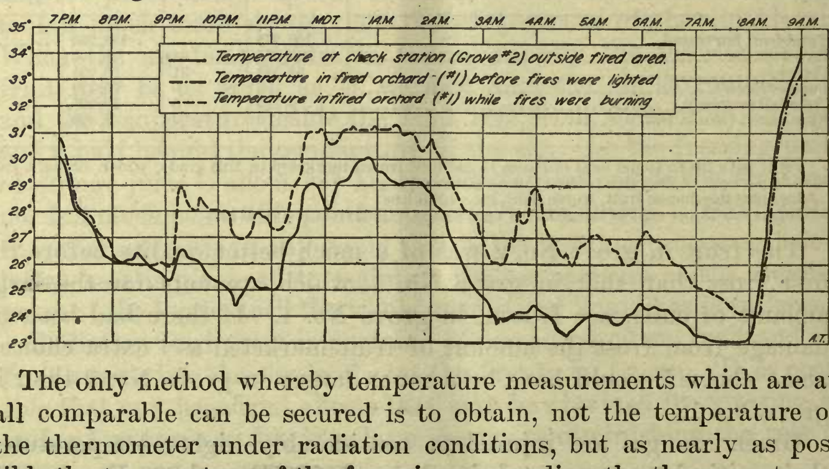
Small green lemons are injured when the temperature remains at 29° F. for some time. Ripe lemons are damaged at 27° F. Lemon blossoms are killed at about 30° F.

METEOROLOGICAL INSTRUMENTS AND EXPOSURES

It has been stated that substances when exposed to a clear sky, steadily lose heat by radiation. Not only does the rate at which ra-



diation takes place vary greatly on different nights, but every individual substance has its own rate at which it radiates heat. Therefore, under conditions favorable for radiation, a thermometer of dark metal would show a lower temperature than one of mercury inclosed in glass.



The only method whereby temperature measurements which are at all comparable can be secured is to obtain, not the temperature of the thermometer under radiation conditions, but as nearly as possible the temperature of the free air surrounding the thermometer.

We have seen that a relatively large amount of heat is required to change liquid water to water vapor. Evaporation is going on at all times, even when the air is saturated, although when saturation has

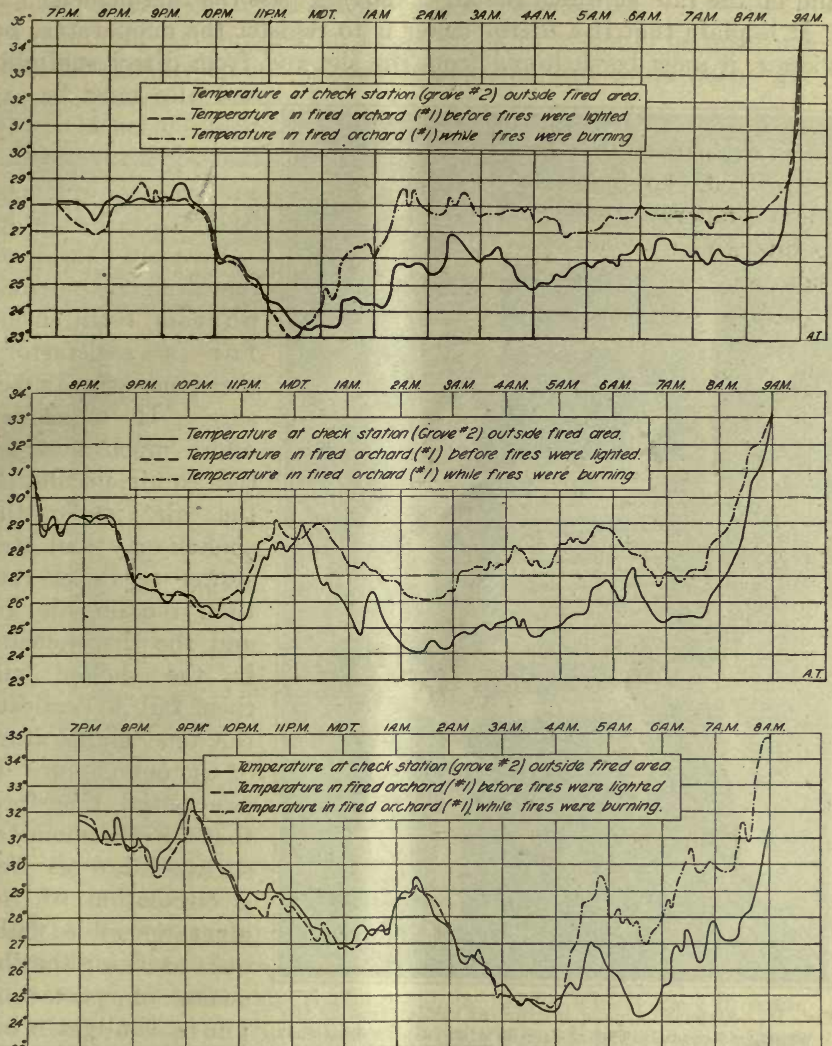


FIG. 17.—Continuous records of the air temperature inside standard instrument shelters in the two orange groves for which the comparative yields are given above. The grove at station C was not protected. The grove at station H was partially protected with coal heaters, set 50 to the acre. Station H was located in a row which contained no heaters and the temperature was probably somewhat higher in the rows containing heaters while firing was in progress. Note that the temperature fell as low as 23° for a short time, without any permanent injury to the fruit. As the weather had been cold for some time before these low temperatures occurred, however, the trees and fruit were considerably more resistant to cold than usual.

been reached, the condensation of vapor balances the evaporation. Evaporation also takes place directly from ice. When a thermometer is covered with a film of water or ice, or contains frost on the bulb, the evaporation that is taking place absorbs heat from the thermometer and cools it to below the temperature of the air. The amount of cooling depends on the amount of moisture in the air and on the rate at which the air is moving past the thermometer.

It is plain that if a thermometer is to register the temperature of the air, it must be sheltered from the sky and from direct sunlight, and also must be exposed in such a way that moisture from any source is not likely to gather on it.

FIG. 18.—Standard type of instrument shelter used by the Weather Bureau. The shelter is always placed so that the door opens toward the north so that the sun can not shine directly on the instruments when the door is open.

Free circulation of the air is also an important requirement for a satisfactory thermometer exposure. If a shelter offers much obstruction to air circulation the air inside the shelter may cool at a slower or faster rate than the outside air and the thermometer in the shelter will then fail to indicate the true temperature of the outside air. It is essential, therefore, that a thermometer shelter allow as free a circulation of the air as possible without sacrificing the elements of protection from sunlight and liquid or frozen moisture. The standard Weather Bureau shelter has a double roof to prevent undue warming of the inside air by the sun's rays, and the bottom is as open as possible. The sides are louvred, the openings being as wide as possible without allowing the direct sunlight to reach the interior. (See fig. 18.)

All thermometers used in determining temperatures in orchards should be exposed with the foregoing principles in mind. A simple but fairly satisfactory method of sheltering a thermometer which is used only at night is to place a large thin flat board horizontally directly above it. The thermometer should be placed close up under the board so as to cut off as much of the sky as possible.

In reading a thermometer on a cold night, care should be taken not to breathe directly on it. Whenever possible, an electric flash-light

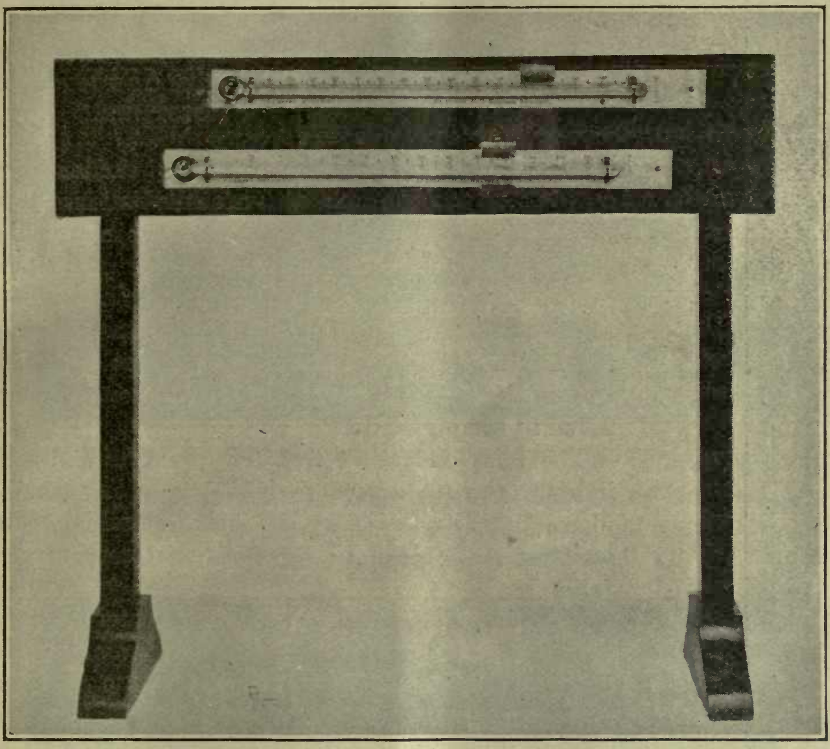


FIG. 19.—Types of thermometers used by the Weather Bureau to register the highest and lowest temperature.

should be used in making readings. When matches or candles are used to illuminate the thermometer, the temperature may be raised a degree or more before the reading can be made, which may in some cases results in loss of fruit through not lighting the heaters in time.

Every orchardist who has frost-fighting equipment should have at least one accurate dependable thermometer to be placed in the coldest part of the orchard, preferably one which will register the minimum temperature. (See fig. 19.) Cheaper thermometers can be scattered throughout the remainder of the orchard. These should be carefully compared with the standard thermometer at least once each year and inaccuracies noted. Those which are found to be in error more than one degree near the freezing point should be discarded. Cards showing the corrections to be applied at different points on the

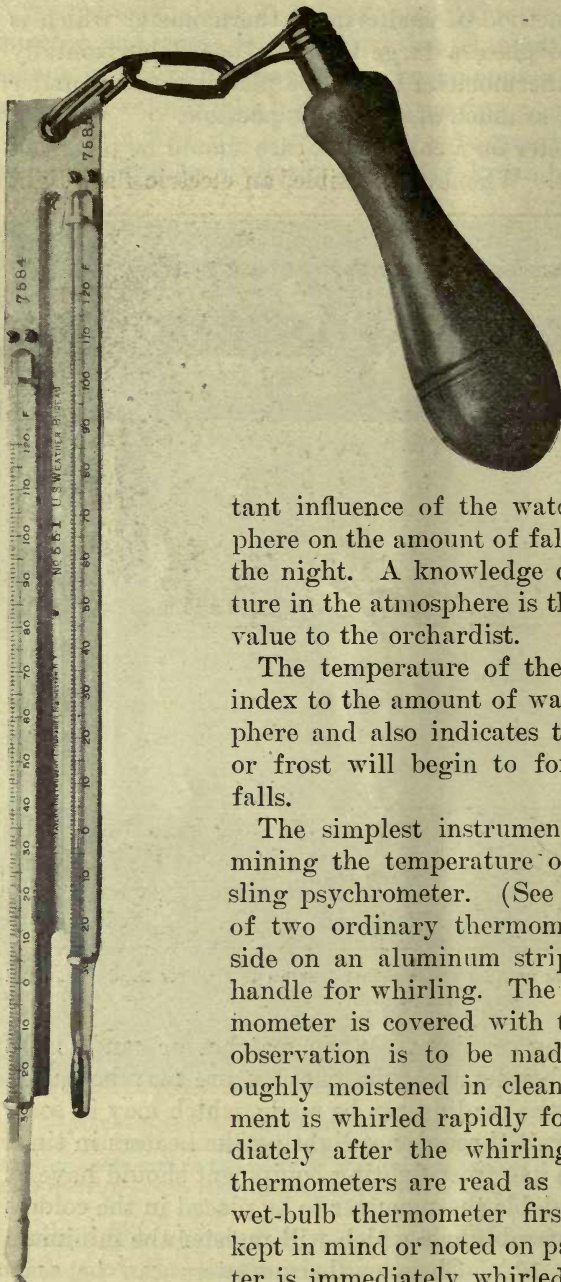


Fig. 20.—Sling psychrometer used to determine the amount of moisture in the atmosphere.

scale to make the readings agree with the standard should be attached alongside all thermometers which are not strictly accurate.

MEASUREMENT OF ATMOSPHERIC MOISTURE.

On an earlier page of this bulletin reference has been made to the important influence of the water vapor in the atmosphere on the amount of fall in temperature during the night. A knowledge of the amount of moisture in the atmosphere is therefore of considerable value to the orchardist.

The temperature of the dew point is a direct index to the amount of water vapor in the atmosphere and also indicates the point at which dew or frost will begin to form as the temperature falls.

The simplest instrument for accurately determining the temperature of the dew point is the sling psychrometer. (See fig. 20.) This consists of two ordinary thermometers mounted side by side on an aluminum strip and provided with a handle for whirling. The bulb of the lower thermometer is covered with thin muslin. When an observation is to be made, the muslin is thoroughly moistened in clean water and the instrument is whirled rapidly for a short time. Immediately after the whirling is discontinued both thermometers are read as quickly as possible, the wet-bulb thermometer first. These readings are kept in mind or noted on paper and the psychrometer is immediately whirled again and more readings are taken. This is repeated several times, until two readings of the wet-bulb thermometer agree closely or until the wet-bulb temperature begins to rise. In other words, it is desired to obtain readings of the two thermometers after the wet-bulb thermometer has reached its maximum depression.

If the wet-bulb temperature falls to 32° F. and remains at that point, the whirling should be continued for some time later, even

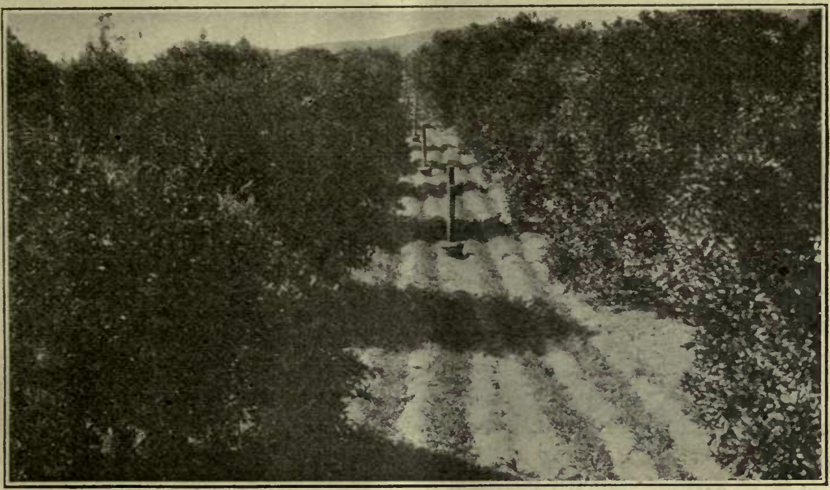


FIG. 21.—Improved high-stack heaters in place in orange grove.

though two or three successive whirlings fail to cause it to read lower. When the water in the muslin begins to freeze, sufficient latent heat is liberated to keep the temperature at 32° until all the water on

FIG. 22.—Short-stack oil heaters in place in an orange grove.

the thermometer bulb is frozen. After this occurs, the evaporation from the ice may cause the wet-bulb thermometer to read below 32°.

After the final readings have been made the wet-bulb temperature is subtracted from the dry-bulb temperature and the temperature of the dew point is found by referring to special tables, usually furnished with the psychrometer.

The psychrometer should be whirled and read in the shade.

FIG. 23.—A corner of a frozen orange dump after a cold season. Thousands of dollars worth of otherwise perfect fruit a total loss through frost damage.

Considerable heat is required to evaporate water, and the heat removed from the bulb of the wet thermometer for this purpose causes its temperature to fall. The less moisture already in the at-

FIG. 24.—Frozen oranges dumped in lemon grove to be plowed under for fertilizer. Very little frozen fruit is used in this way, as most growers believe too much acid is added to the soil.

mosphere the more rapidly the evaporation goes on and the lower is the temperature of the wet bulb. When the atmosphere is saturated the readings of the dry and wet bulb thermometers are the same.

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Ohio Agricultural Experiment Station

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A satisfactory home picture

MONTHLY BULLETIN

OF THE

Ohio Agricultural Experiment Station

VOL. V, NO. 2 FEBRUARY, 1920 WHOLE NO. 50

WHAT SHADE AND ORNAMENTAL TREES SHALL WE PLANT?

Selection of Varieties, Adaptation, Planting and Care

W. E. BONTRAGER

Hardwood species have first choice.—With the passing of wintry days and the approach of the spring planting season, the question of making a suitable selection of trees for beautifying the lawn, street and avenue once more becomes of paramount interest and importance. Well-selected hardwood trees, although in some instances of slow growth for a few years after planting, have a permanence worthy of serious consideration when the choice of planting materials is being made. When once thoroughly established the rate of even the slowest species becomes accelerated and it is safe to assert that at the age of 25 years the oaks will approximate in size most other species that were planted at the same time. On the grounds of the Experiment Station the oaks are becoming the leading trees in a planting scheme designed and planted primarily to illustrate the value of native planting materials.

Nursery-grown stock quite satisfactory.—True it is that such trees when transplanted from a shaded spot in the forest require several years in which to become established, but if nursery-grown stock of the same species be utilized the results will be much more speedy and satisfactory. When properly grown in the nursery, young elms, oaks and maples become accustomed at an early time to having the direct sunlight on all sides and therefore are checked very little when removed to their permanent quarters. The slight additional cost will be much more than offset by the resulting rapid, vigorous growth. The nursery-grown specimen is almost always a well-furnished, stocky young tree, quite in contrast with the slender, poorly-developed weakling brought in from some crowded thicket.

Superiority of the elm and the oaks.—Of the larger trees suitable for lawn and street planting, few of the exotic kinds compare in all-round utility and durability with many of the trees native to the forests of Ohio. It is an encouraging sign to note that the planting of distinctively foreign species is giving way to the utilization of the finer native kinds. For alluvial lands and all rich soils the American white elm is unrivaled in majesty and grace. A moderately fast grower, the elm lives to a very old age, its beauty increasing from year to year. For street planting the elm is unexcelled where soil conditions are suitable.

Our oaks are trees of much dignity, are extremely long-lived and are endowed with a landscape value such as few trees possess. For streets and avenues oaks compare very favorably with the elm and can be grown on a greater variety of soils. One of the finest is the red oak, which has been more widely planted in Europe than any other of our oaks and which is probably the most rapid of all the oaks in its rate of growth. The pin oak is an extremely graceful oak, native to moist lands, that grows well almost everywhere and makes a perfect specimen for the lawn or formal avenue. One of the finest avenues of trees in this country is the celebrated one of pin oaks in Fairmount Park, Philadelphia.

A typical American white elm

The bur oak, scarlet oak and white oak are all good trees that are known to succeed in the latitude of Wooster and over the entire State. Less well known but equally choice and desirable are the chestnut oak, the willow oak, from the South, and the shingle oak (*Quercus imbricaria*), sometimes called the laurel oak, which is one of the richest and handsomest of all oaks in its garb of glossy, dark green leaves. The willow oak, though most abundant in the southern states, has proved to be entirely hardy and satisfactory in Ohio.

A variety of trees.—The cucumber tree is a large northern representative of the magnolias, a group of trees native to a region farther south. The cucumber is a striking, stately species that ultimately develops into a magnificent specimen for the park or roomy lawn. Its foliage is exceptionally large, clean and pleasing. Somewhat similar in size and habit is the tulip tree or whitewood, indispensable where groups and collections of the finer native trees are being assembled. For foliage tropical in its luxuriant richness the great-leaved magnolia (*M. macrophylla*), with leaves often 2 feet long, should be selected. This species ought to be given a sheltered corner to protect the heavy foliage from wind injury. The white ash, the American linden or basswood and American beech are trees having a high landscape value and known to succeed over a wide range of country.

Maples have value.—Probably no group of our native trees has been more popular for lawn planting than the maples. The most lasting of our native species is undoubtedly the sugar maple, although the soft or silver maple has been more commonly planted on account of its rapid growth. Sugar maples ought always to be transplanted before they exceed 2 inches in diameter. For securing early results the silver maple has few equals but it can scarcely be considered a satisfactory permanent tree. The soft, brittle wood is easily damaged by high winds and most old specimens are very much dilapidated. Wier's cut-leaved silver maple is a wonderfully graceful variety of silver maple with a pendulous, weeping habit. The scarlet or rock maple does best on low, moist lands and colors up in autumn extremely well.

The red oak

Gas and smoke resisting trees.—A few trees from foreign countries have high value for street planting through their resistance to dust, gas and smoke. Foremost of these is the Oriental plane or European sycamore, a large, spreading species somewhat similar to its American prototype but in most regards a finer, more desirable tree. The foliage of the plane is quite free from the fungous diseases that disfigure the American tree, while its head is much more adequately supplied with limbs and branches. The Norway maple is another good smoke and gas resister whose merits appear now to be pretty generally recognized. Remarkably free from the ravages of pernicious insects, the foliage of the Norway persists long after the branches of most trees are bare. China has contributed the Ginkgo, a unique tree whose leafage endures city conditions but as yet the Ginkgo has not been extensively used in the formation of avenues.

A group of liquidambar, or sweet gum trees

Trees for restricted areas.—In many villages and towns the lawns are so restricted in size that space can only be spared for medium to small trees. Under such circumstances the liquidamber or sweet gum, from the South, the yellow-wood, a rare flowering tree, the flowering dogwood or perchance a tree or two of birch will be all that can be accommodated. Birches stand much cold, flourish on poor soils and are extremely artistic. The paper or canoe birch and the European white are two very desirable ones, while the cut-leaved variety of the latter, *B. alba pendula laciniata,* is one of the handsomest weeping trees known. The red or river birch has curious, loosely-attached bark and is at home alike on marshy soil and on well-drained upland. Another small tree that is almost a total stranger on lawns is the American persimmon, which assumes much the same shape and size of the common sour cherry and has good, clean, rather glossy leaves.

Ornamental species.—Flowering and distinctly ornamental trees have a legitimate place in lawn planting and are requisites in almost every well-balanced planting scheme. Flowering dogwood, service, judas tree, small magnolias, like soulangeana and others of the Chinese type, the birches, native hawthorns and Chinese flowering crabs are easily handled and are objects of surpassing beauty at certain seasons of the year. The native wild crab apple, the scarlet thorn (*Crataegus coccinea*) and the black haw (*Viburnum prunifolium*) are native trees of great excellence. For improving the banks of a pond or stream the Wisconsin weeping willow has superseded the Babylonian willow which is lacking in hardiness in the North. Red birch and American larch or tamarack are at home in such positions.

The long period of hot weather which we have in late summer and autumn is remarkably favorable to the coloration of leaves and the chief value of a number of our native trees is due to the rich hues which their foliage takes on at this season. For outstanding brilliancy none surpasses the sour gum (*Nyssa sylvatica*) whose flaming canopy is visible for a long distance. The flowering dogwood, too, becomes a study in crimson and scarlet, illuminating splendidly the locality where it is growing. Scarlet or rock maple, sugar maple, ashes and oaks blend into shades and tones of color which are invaluable in the composition of an autumn landscape.

Pruning and spacing.—The pruning of shade trees is a subject concerning which information is often desired, and in a general sense it is safe to say that the matter is usually overdone. During the earlier years of a shade tree's existence but little cutting will be required beyond such as needed to remove broken or otherwise injured limbs or to preserve a moderately symmetrical, well-balanced head. As the specimens grow older and often encroach upon each other or sustain injury from storms, heavy cutting will sometimes need to be done. The indiscriminate topping and heading in of trees, particularly such as is in evidence along most village streets, cannot be too severely condemned. The heavy, unsightly stubs thus produced afford openings through which the germs of decay enter and speedily work havoc to the larger branches and to the trunk. If properly spaced when planted crowding would have been avoided, little or no pruning needed and the lives of the trees would have been very much prolonged.

As to the distance for spacing trees along roads, streets and avenues, the interval between the individual specimens will depend much upon the species and somewhat upon the width of street or road. Along most streets the trees have been planted too closely and very little thinning has been done, hence the presence of tall, pinched, ill-shapen maples and elms in unlimited numbers. Very

Normal development can only be secured when trees are properly spaced

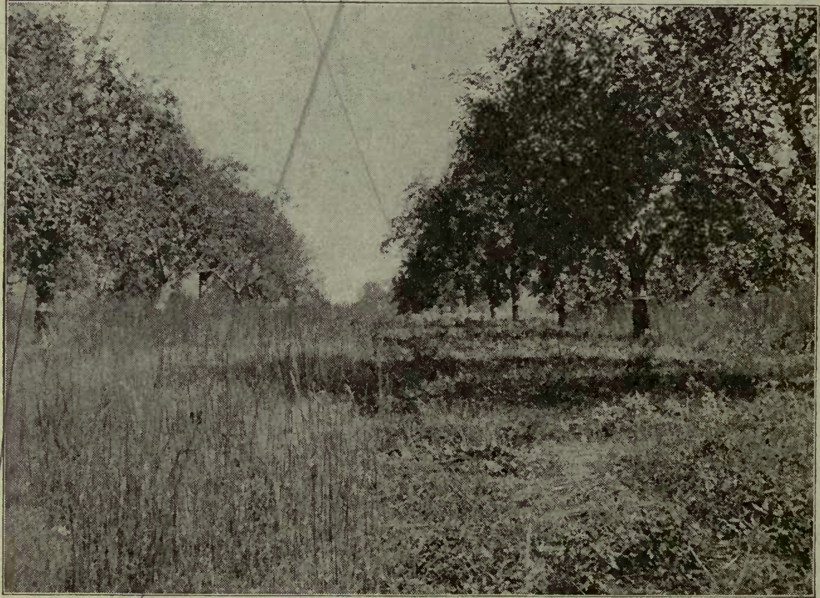
large trees, such as white elm and red oak, should be spaced 60 feet for the former and 45 to 50 feet for the latter. A space of 45 feet will suffice for most other oaks. Tulip tree and cucumber tree should be given 50 feet. American white ash and pin oak should stand 30 or 35 feet. Sugar maple and silver maple should have 40 feet. Ginkgo and liquidambar ought to have a space of 30 feet. Theoretically, the plan of spacing closely and thinning by taking out alternate trees when they begin to crowd is a most admirable one, but reluctance to thin them at the right time generally defeats the original good intentions of the planter.

Care of young trees and planting.—A few words as to the process of planting may not be amiss. When received from the nursery, young stock should be unpacked carefully and heeled in near to the place of planting. For most trees a hole 2 feet across and 15 to 18 inches deep will be about the right size. In this hole the young tree should be set so as to stand about 2 inches deeper than it grew in the nursery. No manure should be used about the fine, fibrous roots, among which the soil ought to be intimately worked and finally well compressed from the top. A mulch of manure, grass or straw will be of great value in carrying the newly-planted trees through extended periods of drought.

Sunshine and pure air are freely admitted here

On the lawn trees should be grouped naturally anu irregularly, no straight lines being allowed to appear. The planting of many large trees closely to a home is not advised. When this is done, sunlight is shut out and a free circulation of air is prevented. It is a good plan to group most of the larger trees along the sides and at the rear of the lawn, placing an occasional specimen near the residence for shade. When a planter is imbued with a determination to practice rigorous thinning at the right time, it is a very good plan to choose long-lived hardwood trees for the lasting effect and among these intersperse a limited number of some rapid grower like silver maple, to be removed when the planting begins to crowd and interfere with the normal, healthy development of the permanent trees.

Production of two rows of Rome Beauty containing eight trees each. Row at right, fertilized, yielded 21 barrels; row at left unfertilized, 9 barrels. Benedict orchard



Row on right, fertilized; row on left, unfertilized. Broom sedge has densely invaded the unfertilized plot, but has not crossed over the plot boundary line into the fertilized plot lighter-pruned trees invariably gave the higher averages in early and generous fruit bearing.

Orchard fertilization.—Fertilization experiments are now being planned for the young apple orchards at the Clermont, Hamilton, Mahoning and Washington County farms, and for the substation farm in Meigs County. Fertilization work also will be begun at the Belmont County farm within the next year.

Landscape improvement.—Improvement of residence grounds, in connection with the county and district experiment farms, also is a part of the horticultural department's service. Measuring, mapping, planning and planting are being accomplished as rapidly as limited time, scarcity of help and widely scattered farms will permit. There are twenty-one separate residence grounds at the ten county and two district farms at which some planting has been done. A single visit to all of these farms necessitates very nearly 800 miles travel.

From the horticultural viewpoint the county experiment farms, so recently established, could not reasonably be expected to be productive of much interesting data for some years; but, when results begin to appear, these farms surely will be a source of abundant material for illustrative and educational purposes.

COSTLY CLOVER SEED AIDS ALFALFA CULTURE

The high price of red clover seed is likely to cause farmers to grow more alfalfa, according to specialists at the Ohio Experiment Station. Alfalfa seed costs about the same as red clover seed but when a good alfalfa stand is secured it will produce abundantly without reseeding for three to five years and a larger tonnage of hay to the acre may be grown generally with alfalfa than with clover.

Alfalfa thrives well where good drainage is provided, where there is plenty of lime in the soil and where the soil is in a fair state of fertility.

Alfalfa culture methods differ. In the western part of the State the alfalfa is frequently sown in regular rotation similarly to red clover. In eastern Ohio it is generally sown as a regular crop in midsummer—last of June to the first of August—and allowed to remain 4 or 5 years or as long as the stand will justify.

Ten pounds to the acre of seed at the Ohio Experiment Station has given better results than when sown at the heavier rate. The seed should be inoculated.

SELECTING NURSERY STOCK

Standard Varieties, Locally-grown Plants and Clean Trees Required

PAUL THAYER

Varieties.—It is always safe to choose from the standard varieties. Novelties come and go; or most of them go. Occasionally a new variety, like the Elberta, is really valuable and enriches everyone who has the courage to plant it while still untested. For every one of this kind, however, there are several much-heralded novelties that prove to be a bitter disappointment to the planter. Standard varieties have been tested out on different soils and under widely varying conditions; they have their weaknesses which are well understood, but they have withstood the competition of past years and represent the "survival of the fittest."

Local conditions often govern the selection of varieties. The orchardist who plans to sell the crop as a whole in the orchard should confine his varieties to three or four, while the grower who expects to depend upon local markets usually plants a succession of varieties ripening throughout the season. Shipping quality, which is of prime importance in the former case, might be left out of consideration in selecting varieties for the local trade.

Mean and extremes in nursery stock

"Pedigreed plants" is a catchword used by several nurseries to secure trade or to justify the prices charged. It has been definitely proven by Prof. Shamel, of the Bureau of Plant Industry, that with citrus fruits, such as the orange and lemon, there is a wide variation between trees of the same variety and that this can, to some extent at least, be transmitted by grafting. Unfortunately the first half of this theory almost nullifies the last half. All trees of any variety have grown from pieces (scions) of the original tree or from the other trees propagated from it. If these vary so as to give us "superior" and inferior trees will not the same law affect the (graft) descendants of these "superior" trees? In other words, can we say that bud variation has given us improved strains but will now cease to exert any influence and permit us to propagate from these improved types with perfect assurance that "like produces like"?

For further advice as to varieties one may turn to the publications of the agricultural colleges and experiment stations. Dependable Fruits, 313, and Apple Varieties, 290, of the Ohio Experiment Station, give much of value for Ohio planters. Besides bulletins there are nursery catalogues, reports of horticultural societies, and discussions in the agricultural press.

Nursery.—Always buy trees or plants direct from the nursery, never from an agent, unless the agent is personally known to you and is one in whose judgment and integrity you have enough confidence to make him your agent.

There is a little advantage in attempting to get trees true to name in buying from from the small nursery over the large one when the proprietor of the small nursery gives his personal attention to the work of propagation. This is only true when the small nurseryman grows his own stock. Every time a nursery tree changes hands it increases the possibility of error and decreases the responsibility of the dealer who finally sells it to the planter.

Crown gall on roots of young tree

In studying nursery catalogs discriminate against those making extravagant claims or listing marvelous new "bugless" and "blight-proof" varieties. The list of truly desirable varieties does not change much from year to year or from catalog to catalog. Each year a very few meritorious, new varieties appear but any catalog listing a lot of wonderful new kinds is to be looked upon with suspicion.

The location of the nursery is unimportant except in two particulars. There is a distinct advantage when the nursery is near enough so that the buyer may visit it and personally select the stock and thus know just what he is getting. Berry plants, especially black caps and strawberries, do not stand shipment as well as trees and vines and if poorly packed or delayed in transit they may arrive in poor condition. For this reason it is best, whenever possible, to get these plants from plantations near home. With potatoes and some garden seeds there is some difference in behavior, depending upon the latitude in which the seed was grown and this has led many to believe that a similar difference might exist between nursery stock from different sections. In order to maintain our variety fruit collections at the Experiment Station we annually order trees and plants from probably between 25 and 50 different nurseries located in all parts of the country from Ontario to Georgia and Texas and from Maryland to Oregon. We have failed to find any evidence to prove that a tree or vine from Georgia or Texas is in any way inferior to the same variety from Ohio and New York. Many southern varieties are unsuited for northern culture and behave differently here than in their native state so that one must make allowance for the descriptions of southern varieties in southern catalogs, but duplicate lots of trees from Georgia, Ohio and Ontario, if equally mature and equally rooted would grow equally well and be equally hardy. It is advisable, however, to avoid planting southern-grown trees in northern latitude in the fall. This is because southern-grown trees do not mature early enough to be planted in the fall in cold climates.

Woolly aphis causes distorted growth

Trees and plants.—Having selected the list of varieties and the nursery from which they are to come, there remains only the selection of the plants themselves. If the nursery is within easy reach it is well if the planter can personally select his own trees. The experienced planter will not be so much concerned that the bodies be perfectly straight and smooth as he will that the roots be numerous, well spread and stout and the top and roots be clean and vigorous. Never plant a cull or second grade tree. There is, however, a world of difference between a second *grade* tree and a second *size* tree. A second size tree has all the possibilities of the first size

Nursery stock heeled in for winter

tree but simply grew in a more crowded portion of the row. In this connection note the three peach trees in the illustration on page 58. The horizontal line shows where the three trees should be normally headed at planting. If this is done the heavy one at the left will be cut back beyond the strong buds, and dependence will have to be placed upon the weak branches which are so often injured in packing, or upon adventitious buds, for the top. The middle tree is a medium-sized tree. Topping at the indicated height will leave a number of strong buds to form the head. The third tree, scarcely discernible against the background, does not reach the line and is too weak to waste room upon in the orchard. City people are more susceptible to the charms of oversize trees than experienced orchardists.

One year from the bud is the usual age for peach trees. Apple, pear, plum and cherry trees may be 1 or 2 years old. Occasionally older trees are offered for sale but they should be avoided under ordinary conditions. Year-old trees are slender, straight whips which may be headed at any desired height and made to conform to the idea in the mind of the planter. On account of their size they are easily lost amid the weeds and easily fall victims to the disc harrow or the mowing machine. The 2-year-old tree was topped when a year old and has a number of branches from which to select the one desired for the head of the new tree. The tree is larger, less easily injured and a little more able to withstand unfavorable conditions.

Not so much is heard now about the relative value of budded and grafted apple trees. In certain sections,. such as the prairie states, the method of propagation may be of importance but it is immaterial to the Ohio orchardist.

Clean nursery stock important.—Above all, one should plant clean trees. The three pests to be found most commonly on nursery stock are crown gall, woolly aphis and San Jose scale. The last is the least dangerous since it can be destroyed by spraying or dipping the tops of the young trees in the solutions used for the regular dormant spray given in the spray bulletins. Single scales appear as circular dots about the size of the head of a pin, usually on a slightly-sunken area of bark, the bark being frequently tinged with red. On badly-infested trees the scales give the limb an ashy gray appearance; they may be rubbed off with the thumb nail or the back of a knife blade.

The woolly aphis is not so easily controlled and any trees showing signs of infestation with this pest should be rejected. The indications of woolly aphis are marked swellings on the roots and sometimes grayish masses of aphis clustered between the roots. Sometimes a small root, when badly attacked, is swollen so that it resembles a string of beads.

Equally objectionable are trees infested with crown gall, or hairy root as one form of it is called. This disease appears in the form of wart-like excresences on the body limbs or roots of trees. The most common location is at the base of the trunk where the trees was grafted or budded. When this growth occurs beneath the ground it frequently puts forth a mass of fine fibrous roots. While sometimes the crown gall does not seem to injure the tree, it often causes severe injury and affected trees are not fit for planting and should be rejected.

SMUDGING TO PREVENT FROST

W. J. GREEN

The protection of fruit and vegetable plants against frost has been widely practiced, especially in the coast regions of the extreme west. It has not been so generally practiced in the eastern states but there are few localities where the plan has not been tried to some extent. At one time smudging was looked upon by many as one of the essential horticultural operations but belief in it as a practical and necessary item of orchard practice is less firmly held than formerly.

The main reason for the change in opinion is because of the cost of such work and uncertainty as to results. The temperature can be raised in this manner but it often happens that when one has spent considerable time and money in smudging against a looked-for frost the temperature does not fall below the danger line. This makes smudging of very doubtful utility, even though it is sometimes the means of saving a valuable crop.

Wood and coal are not satisfactory materials for smudging as they require too much labor and respond too slowly when it is desired to raise the temperature quickly. Crude petroleum, burned in suitable heaters, will raise the temperature quickly and hold it for a considerable time, but one cannot be sure that a frost will occur even though it is predicted by the officials of the weather bureau.

Just when to begin lighting the heaters can be determined only approximately even though a constant watch is kept through the night. Heating in winter to protect fruit buds is even less practicable than heating to protect blossoms in spray time.

Mulched strawberry beds may be set on fire unless a considerable space around each fire pot is left uncovered. There is danger, also, of setting fire to grass and straw with heaters in mulched orchards.

While it is true that there are considerable losses by burning oil in orchards when not needed it may be due, in some cases, to over zealous orchardists who are anxious to try something new. The fact should not be overlooked, however, that orchard heating is an expensive operation even when no unnecessary work is done.

PUBLICATIONS OF THE OHIO AGRICULTURAL EXPERIMENT STATION

The publications of this Station are now issued in three series, namely:

1. The Monograph Bulletin, each number of which is a record of progress in a single line of investigation. This series is a continuation of both the ordinary and the "Technical" series heretofore issued and is largely technical in character.

2. The Monthly Bulletin, each number of which contains several brief and timely reports of progress in different phases of the Station's work, including nontechnical abstracts of the Monograph Bulletins.

3. A Weekly Press Bulletin, containing brief notes on the Station's work, prepared for newspaper circulation. The more important of these notes are republished in the Monthly Bulletin.

These publications are sent free on request. The addresses of those who request that their names be placed on the mailing list will be entered for the Monthly Bulletin only, unless either of the other series is definitely requested. Address Mailing Room, Experiment Station, Wooster, Ohio.

RECENT MONOGRAPH BULLETINS

No. 321—Tomato diseases in Ohio: Descriptions and control measures recommended for rhizoctonia, Fusarium wilt, bacterial wilt, stem rot, leaf spot, blight, anthracnose, rot, "leak," leaf mold and other diseases common to growing tomatoes.

No. 322—Feeding experiments with laying hens:—Range vs. confinement, variety vs. simple rations, various amounts of protein, methods of feeding, date of hatching, corn vs. wheat.

No. 323—County Experiment Farms in Ohio: Annual reports for 1916 and 1917.

No. 324—Ohio weather for 1917.

No. 325—Thirty-seventh annual report: Projects under investigation, financial statement for 1917-1918, index to technical bulletins.

No. 327—Clover vs. alfalfa for milk production: Discussion and summary tables of feeds, production, groups of cows used and individual summaries.

No. 328—Livestock vs. grain farming: Relative profits in livestock and grain farming, labor required in both types, crops and fertility considerations.

No. 329—The peach tree borer: Life history and habits, natural enemies, testing of remedies for control, recommendations for control.

No. 330—The mineral metabolism of the milch cow: Minerals needed by dairy cattle, feeds that supply minerals, the practice of feeding bone flour, the necessity of legumes in the ration.

No. 331—The farmers' elevator movement in Ohio: Early history, location, methods of operating and suggestions for organizing companies.

No. 332—Destructive insects affecting Ohio shade and forest trees.

No. 333—Apple blotch, a serious fruit disease.

No. 334—Dairy production in Ohio: Results of cooperative tests, costs in production and suggested methods of fixing milk prices.

No. 335—Effect of age of pigs on the rate and economy of gains.

No. 336—The maintenance of soil fertility: A quarter century's work with manure and fertilizers.

No. 337—Ohio weather for 1918.

No. 338—Thirty-eighth annual report: Projects under investigation, financial statement for 1918-1919, index to technical bulletins.

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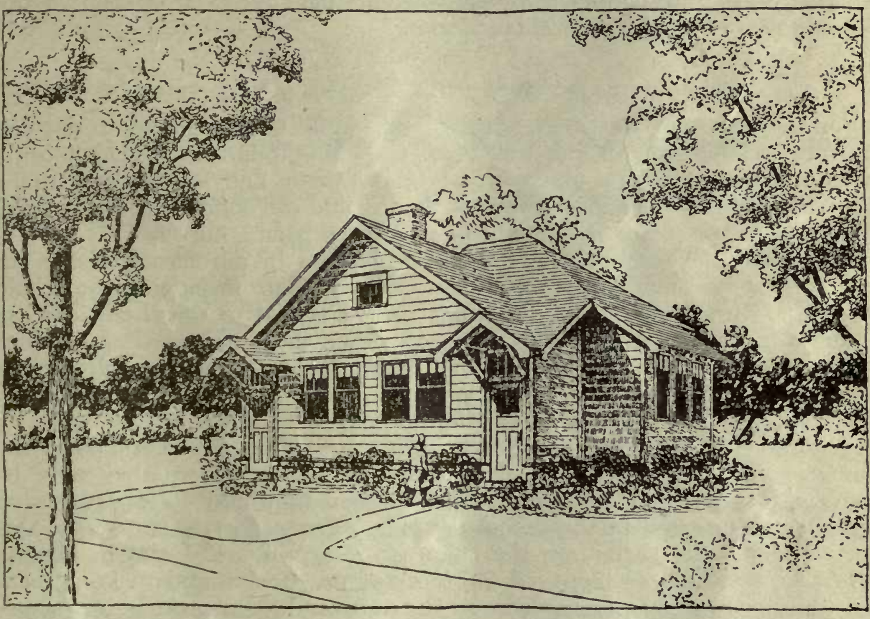
CIRCULAR NO. 36 FEBRUARY, 1919

MICHIGAN AGRICULTURAL COLLEGE

EXPERIMENT STATION

HORTICULTURAL SECTION



PLANTING THE RURAL SCHOOL GROUNDS

By C. P. HALLIGAN

EAST LANSING, MICHIGAN
1919

PLANTING THE RURAL SCHOOL GROUNDS

General Aim

Any plan for the improvement of the school grounds should first of all be simple. No elaborate or pretentious effects should be attempted in their development. The primary aim should be to retain and increase the natural beauty of the surrounding scenery, making the grounds a beauty spot in the rural landscape, rather than a formal, artificial, or imported element in the scenery. A school ground should possess the same general character of beauty as is indigenous to the neighborhood, making it appear not as something separate and distinct from the surroundings, but as an attractive and pleasing portion of the general landscape.

Use of Native Plants

For these reasons the trees, shrubs, and plants that are used to develop the rural school grounds can well be of the kinds found in the neighboring fields and woods. Such plants will be naturalistic and harmonious in the landscape, and better adapted to the climatic and soil conditions of the place than some exotic plants that might be purchased from a nursery.

Therefore, the expense that might be incurred in purchasing plants for this work should not detain ambitious teachers from developing the school grounds. Nursery plants of the kinds most adapted to the conditions are easier to transplant successfully because of their more branched and fibrous root systems, but similar kinds from the fields may be successfully transplanted if the work is carefully and properly done.

The interest and enthusiasm of children may be aroused for this work by arranging field excursions in the early spring,—which is the season when the plants should be transplanted,—to fields and woods, where they may be found, and where under the teachers' direction they may be carefully dug and then transferred to the school grounds. The earlier in the spring this work is done, the better are the chances of success. The aim in digging should be to retain as many of the roots as practicable and to keep them moist and protected from exposure to sun and wind. In so far as it is sometimes difficult to identify many of the plants in early spring when there is no foliage upon them, it is often desirable to have field excursions in the early fall while the leaves are still on the plants and to mark such plants as are desired for spring planting. Such an excursion could be made in connection with a lesson in Botany or Nature Study work.

The Planting Plan

Before the planting is started a plan should be drawn to a definite scale (say of 1″ to 10′), showing the size and location of all existing buildings, walks, drives, plantings and boundaries of the property. With this data as a basis a complete planting plan of the property may be made. The execution of the plan then may be gradual. The most important parts may be developed first and the others as circumstances permit. Such a plan will then serve as a definite record for future reference, and will tend to insure the progressive development of the scheme that otherwise might be forgotten.

Where to Plant

Trees should be planted about the boundaries of the property for shade and general protection against the winds; also in the rear of the buildings to produce a proper back ground. The trees may be arranged to enframe the building and to hide undesirable views either within or without the property.

Hardy shrubs are especially desirable in masses or groups about the boundaries of the lawn, and about the foundation of the school building; also in front of the out-buildings and other undesirable elements, as screens, and sometimes as a hedge to take the place of an undesirable fence.

Vines may be used to cover walls, fences, out-buildings, banks or may be trained about the entrance of the porch. With wooden buildings they should not be used to cover the sides of the structure as they are very apt to induce the wood to decay.

Rules for Planting

The following general rules should be observed in planting:

1. Preserve as many of the fibrous roots as possible.
2. Expose the roots as little as possible to the drying influences of the sun and wind.
3. Prepare the roots for planting by cutting away the bruised and broken portions.
4. Plant an inch or two deeper than the plant stood in the field. If the soil is very sandy, the plants may be set two to four inches deeper.
5. Dig the hole in which the plant is to be set deep enough to receive two or three inches of fine top soil before putting the plant in place, and make it wide enough to allow the roots to spread in their natural position without crowding.
6. See that good friable surface soil is firmly packed beneath and over the roots.

Native Plants Available

A suggestive list is here given of the more common native plants, that may be available in neighboring fields, for improving the rural school grounds:

Native Trees

Sandy Soil	*Medium to Heavy Soils*	
Jack Pine	Sugar Maple	Elm
White Pine	White Spruce	Red Maple
Carolina Poplar	White Oak	Linden
Red Oak	Beach	Alder
Sassafras	White Cedar	Hemlock
Large-toothed Aspen	Tulip tree	Swamp Oak
White Birch	Iron-wood	Peach-leaved Willow
Red Cedar	American Ash	Black Willow
Hawthorn	Black Walnut	Flowering Dogwood
Sycamore	Sheepberry	
Hop-tree		

Native Shrubs and Herbaceous Plants

Prairie Rose (Rosa Setigera)
Staghorn Sumac
Dwarf Sumac
Sand Plum
Prairie Willow
Bush Honeysuckle
Common Juniper
Trailing Juniper
Sweet Fern
Common Braken Fern
New Jersey Tea
Wild Rose (Rosa Humilis)
Red Elder (Shade)

Wild Rose (Rosa Carolina)
Black-berried Elder
Hazel
Button Bush
Red Dogwood
Winter Berry or Black Alder
Shad Bush
Spice Bush
Willows (Several native varieties)
Flowering Raspberry
Black Haw
Arrow-wood
Hardhack
Meadow Sweet
Bladdernut
Snowberry
Indian Currant
Sweet Gale
Christmas-fern (Shade)
Ostrich-fern (Shade)

Native Vines

Bitter Sweet
Honeysuckle
Wild Grape

Virginia Creeper
Moonseed

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TEXAS AGRICULTURAL EXPERIMENT STATION

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

W. B. BIZZELL, President

CIRCULAR NO. 20 FEBRUARY, 1920

PATCH-BUDDING LARGE LIMBS AND TRUNKS OF PECAN TREES

B. YOUNGBLOOD, Director
College Station, Brazos County, Texas

Circular No. 20. February, 1920.

PATCH-BUDDING LARGE LIMBS AND TRUNKS OF PECAN TREES

BY

J. A. Evans.*

It is sometimes estimated that there are 100,000,000 wild pecan trees in Texas. Certainly it would be within the mark to say there are half that number, and possibly one-half of these trees are small enough in size to make it practical from an economic standpoint to top-work them.

A pecan tree to be classed as good, must, first of all, be a heavy and regular bearer. After that, it must bear nuts of fair to large size, of thin shell, full meat, and rich flavor, and the shell must crack easily and part readily from the kernel.

From time prehistoric to the present, every such tree has been known and visited by the whole nut-eating range of the animal kingdom—from jaybird to wild turkey, from squirrel to wild hog, and from Indian to sorry white man—and very few, if any, of the nuts escaped to germinate. It was the little hard nut that got by and produced the next generation of trees.

Thus it can be seen that the general trend in the process of evolution has been one of deterioration in point of fruit.

Out of all the millions of trees in Texas there are probably not more than twenty that are really worthy of propagation by budding and grafting—that is to say, there is a very limited number of trees of surpassing excellence from which buds should be taken, and from none other.

Since it is possible by the use of these buds to transform a tree that bears a light crop of poor nuts into a tree that will bear a heavy crop of good nuts, something of the importance of this work may be comprehended.

Realizing this importance, some of the pioneers in pecan culture set about the work some twenty years ago, but with very limited success. The universal custom in the beginning was to cut the trees back severely —in fact to mere stumps—in order to force out new sprouts on which to bud. Some of these sprouts were removed, being very numerous, and the others were budded when large enough. It was very weakening to the tree to be deprived of most of its leaves during the season, but that was not the end of it. The budded sprouts must in turn be cut back in order to force new growth from the inserted buds. Thus the tree was deprived of most of its leaves the second season, and continued to suffer an insufficiency for two or three years more. In their weakened condition the trees fell easy prey to borers, and many of them

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*Pecan Specialist, Extension Service, A. and M. College of Texas, in cooperation with Texas Agricultural Experiment Station.

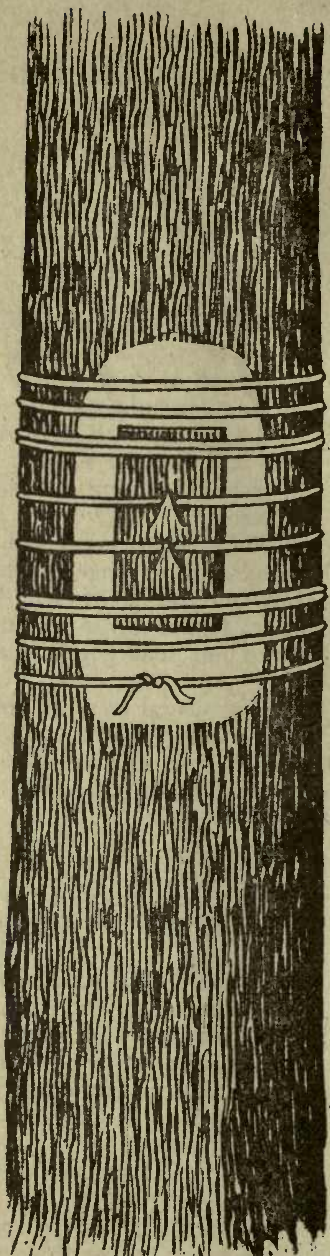

Figure 1.—The patch bud.

died during drouths. Of those that managed to live, few regained their former vigor.

The first improvement over the old system came with the introduction of the bark graft. Why not insert a graft under the bark at the ends of the stubs when the tree was cut back early in the spring? If the graft should unite and grow, the second cutting would not be necessary; and if it failed to unite, the sprouts would come just the same.

Unquestionably this was an improvement; but still the first cutting was necessary, and a high percentage of success was very difficult to obtain with the bark graft. Moreover, the nature of the union was such as to render splitting-off likely by the force of the wind against the vigorous new growth.

Having in mind the importance of the work and the weak points in the systems previously followed, the Texas Agricultural Experiment Station set about finding a means of top-working trees of considerable size without cutting them back, while at the same time securing a high percentage of successful operations.

It has been discovered that it is not necessary to have young sprouts with thin bark as stocks for budding. Buds can be successfully placed on limbs of any size, theoretically, though it is not practical to place them where the limbs are more than two inches in diameter, as the wound made by cutting back, after the bud has united, will be too long in healing over. The limiting factor in the size of limb or trunk to be budded is the wound made by cutting back, just as is the case with grafting. Any limb that is not too large to be cut back for grafting is not too large to be budded.

Figure 1 will make the operation of patch-budding in thick bark quite clear.

Before the bud from the scion is inserted, the bark of the stock should be trimmed down thin to match the bark of the bud. The pared place should be about two inches long and one and a half inches wide. One must be careful not to cut through the phloem cells in the bark of the stock while doing the paring. After the bud-patch from the scion has been placed in the matrix and tied in as shown in Figure 1, the whole pared surface, including the edges of the matrix, should be lightly waxed over to prevent drying out through evaporation. It is not necessary to wax over the bud segment as its outer bark has not been disturbed.

Following is the recipe for the wax used:

Rosin two parts and beeswax one part. Melt together and set off to cool. When it is nearly ready to resolidify, pour in wood alcohol, stirring all the while. Continue till the mass is bright yellow in color and quite soft. The quantity of alcohol necessary is about two-thirds the volume of the other combined materials. Grain alcohol is best; wood alcohol will do, but *denatured alcohol will not do.*

The binding strings should be cut about three weeks after the buds were put on. The strings are likely to cut into the bark and interfere with the circulation if left for a longer period. In fact, it is thought that many buds are killed by the strings in this way. Experiments with rubber bands instead of strings showed a higher percentage of living buds. If the rubber bands are used they need not be cut at all, as they will decay from the action of the wax and will break before the three-weeks period is out.

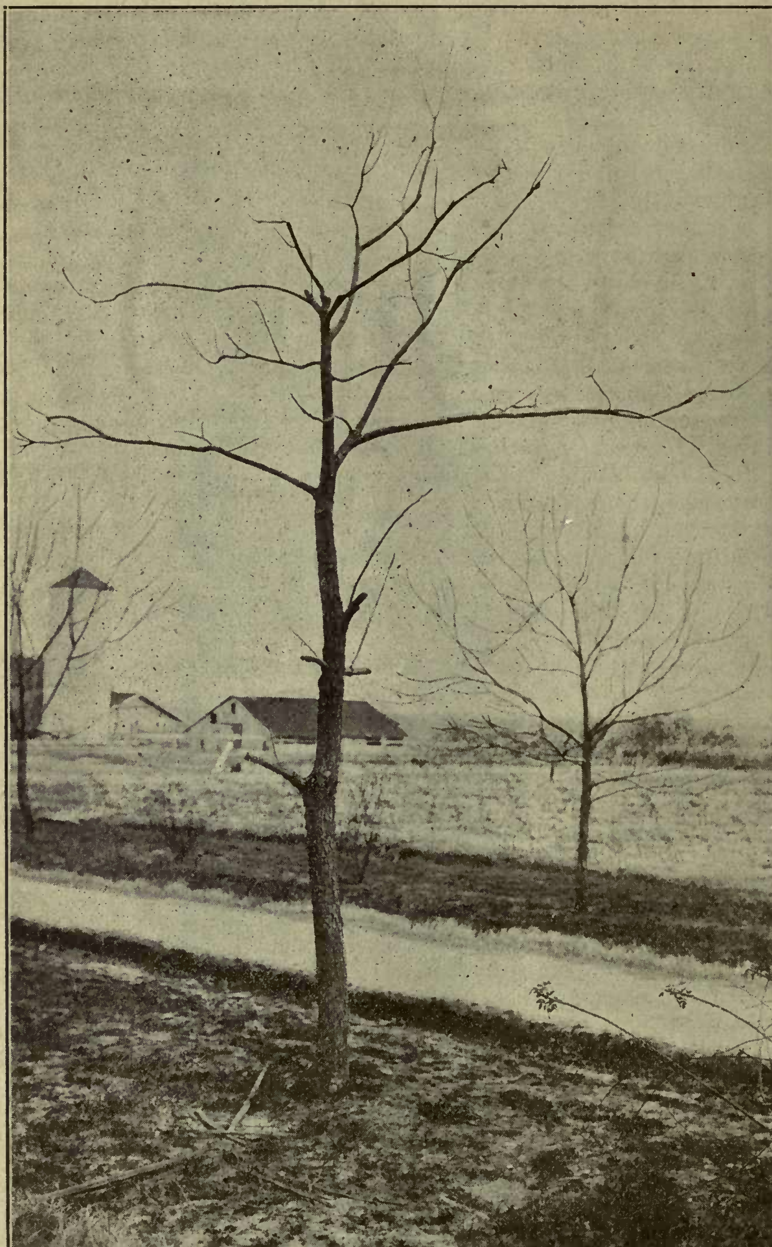

Figure 2.—Pecan tree after budding.

The buds will have formed a good union by the end of three weeks if they are ever going to do so and the budded branches should then be cut off at a point a foot beyond the buds in order to force them out. Some branches just above the buds should also be cut off close to the body of the tree so as to let in the light and air and to leave room for the new growth from the buds.

Figure 2 is a photographic reproduction of a tree worked by this method on the grounds of the Experiment Station at College Station, Texas, April 7, 1919. The tree is six inches in diameter a foot above the ground, and the four budded limbs range from an inch to two inches in diameter near the body of the tree. Each of the four branches grew toward one of the cardinal points of the compass, and their arrangement, one above another, obviates the formation of a crotch. Not so much as a single leaf of this tree was cut at the time of budding, and had the buds not lived the tree would have been neither mutilated nor weakened. Examination three weeks after budding, however, showed the buds to have united, and the branches were then cut as above suggested, and all branches above the budded ones were removed for a distance of three feet.

The growth from the buds is now (November 26, 1919) from two to three feet in length, and is in vigorous condition. The top of the tree will be cut out just above the topmost budded limb before the sap rises in the spring, and the forced growth of the budded portion will soon provide leaves enough to perform the full functions of a top.

A tree three inches in diameter that had grown in a forest and had no low branches for budding had a new head formed in this way. The buds were placed on the trunk of the tree five or six feet above ground, and were forced out, not by cutting off the top of the tree, but by wounds just above the topmost inserted bud. Each wound was a slight saw-cut directly above the bud to be forced. The combined effect of the wounds was not sufficient to entirely obstruct the passage of elaborated plant foods, but each wound did obstruct the pathway of passage to its particular bud, and thus forced it out.

The top of this tree will be removed before spring.

All remarks about forcing buds apply, in point of time, to only those operations performed before midsummer. Buds put on after that time should be left dormant till the following spring, when the same methods of forcing should be applied.

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BULLETIN No. 466. SEPTEMBER, 1919.

New York Agricultural Experiment Station.

GENEVA, N. Y.

SPRAYING LAWNS WITH IRON SULFATE TO ERADICATE DANDELIONS.

M. T. MUNN.

PUBLISHED BY THE STATION.

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*Connected with Grape Culture Investigations.

BULLETIN No. 466

SPRAYING LAWNS WITH IRON SULFATE TO ERADICATE DANDELIONS.

M. T. MUNN.

SUMMARY.

Experiments made at the Station during the past eight years demonstrate that dandelions may be eradicated from lawns, at relatively slight expense and without material injury to the grass, by proper spraying with an iron sulfate solution. Ordinarily, four or five applications are required. The first spraying should be made in May just before the first blooming period. One or two others should follow at intervals of three or four weeks; and, finally, one or two more in late summer or fall. During the hot, dry weather of mid-summer spraying should be discontinued because of the danger of injury to the grass. A conspicuous blackening of the lawn which follows each application soon disappears if the grass is growing vigorously. Of the other common lawn weeds, some are killed while others are but slightly injured by the spraying. Unfortunately, white clover, also, is killed. Spraying should be supplemented by the use of fertilizers and the application of grass seed in the spring and fall of each year. With proper management it is necessary to spray only about every third year in order to keep a lawn practically free from dandelions.

The cutting-out method of fighting dandelions is laborious and ineffective unless the greater part of the root is removed. Shallow cutting, unless done frequently, is worse than none at all, because each cut-off root promptly sends up one or more new plants.

Tests of certain after-treatment measures in the form of reseeding, liming of the soil, and fertilization with commercial fertilizers and stable manure, used in conjunction with the spraying operations, gave results which serve highly to recommend their use either singly or in combination on lawns.

A study of seed production in the common dandelion shows it to be parthenogenetic, that is, capable of producing viable seeds without fertilization of the ovules by pollen.

INTRODUCTION.

From experiments conducted at this Station during the years 1909 and 1910 by G. T. French, then Assistant Botanist, and reported in Bulletin No. 335, the conclusion was drawn that the spraying of lawns with iron sulfate solution to kill dandelions is unlikely to prove successful in New York. The apparent failure to kill large, vigorous plants was explained upon the ground that spraying merely kills the leaves, and therefore has only a starving effect upon the roots in the same manner as frequent cutting. However, a survey of the literature of the subject prior to 1912, the time the experiments discussed in this bulletin were started, revealed the almost unanimous recommendation of the use of iron sulfate solution as an effective means of controlling dandelions in lawns. In 1907, Bolley, in North Dakota, reported the results of experiments conducted between 1896 and 1907. It was stated by this author that a new method of fighting dandelions, namely, spraying them thoroly at stated intervals with a differential spray solution made by dissolving two pounds of iron sulfate in one gallon of water will give success, and that the grass need not be injured. This work was more fully discussed in 1908 and some additional measures of control suggested. Again, in 1909, Bolley reported that on large lawns spraying dandelions with iron sulfate is quite practical and the cost, using field sprayers, is less than for mowing. Note was also made of the fact that the iron sulfate has a beneficial effect upon the grass in the direction of the prevention of certain diseases of blue grass. In Rhode Island, Adams (1909) found that dandelions may be held in check and practically eradicated from lawns by spraying four or five times during the season with a twenty per ct. solution of iron sulfate, but that complete eradication cannot be expected because of the fact that the lawns are reseeded by wind-blown seeds. This investigator reported no injury to the grass when the spraying was done about two days after mowing. Experience demonstrated that the most effective spraying was made in the spring when leaf growth was vigorous and the first buds ready to open. Reseeding of the lawn after spraying was also advised.

According to the report of Pammel and King (1909) two sprayings with a twenty per ct. solution of iron sulfate killed many of the dandelion plants in a plat of lawn at Ames, Iowa. Chickweed, also, was killed.

Moore and Stone (1909) reported satisfactory results in Wisconsin from the use of a twenty per ct. solution of iron sulfate sprinkled on lawns with a sprinkling can. Plants not killed by the solution were sprinkled with dry iron sulfate soon after the spraying. This application killed nearly all the remaining plants and apparently caused no injury to the grass.

In South Dakota, Olive (1909) reported that the results obtained from spraying dandelions with iron sulfate were not as favorable as those reported by other experimenters. However, young plants were killed by one application, while old, large plants required three or more applications. This worker suggested that, possibly, continued use of the spray for two seasons would give better results.

Selby (1910) mentioned the fact that, in Ohio, tests of iron sulfate show that the first spraying should be made before blossoming of the dandelions, and stated that two or three later sprayings would probably be found advisable.

At the time of the preparation of this bulletin for publication a survey of the literature reporting recent work on dandelion spraying shows that nearly all investigators are agreed that iron sulfate has considerable value as a dandelion eradicator. In Canada, Fyles (1913) sprayed dandelions with a solution of iron sulfate, two pounds per gallon of water, and reported that after the third application the weeds were still living altho much of their foliage was destroyed. After the third application the spraying was discontinued since the injury to the surrounding grass was greater than to the weeds. No mention is made of the location of the trials, but it is inferred that they were made on lawns. A little later, however, Howitt (1913) reported that after six sprayings with a twenty per ct. solution (two pounds per gallon) of iron sulfate applied with a knapsack sprayer to plots of lawn containing 168 square feet the dandelions were reduced in number over ninety per ct. Aside from the black discoloration which immediately followed spraying and disappeared in a few days, no permanent injury was caused to the grass. In fact, it was noted the following spring that the grass on the sprayed plats was greener and more luxuriant than on the unsprayed plat. In 1913 a one-eighth-acre plat was sprayed six times with a power sprayer using a solution of similar strength. The results obtained were said to be as satisfactory as those secured with a knapsack sprayer. At least ninety per ct. of the dandelions were destroyed. The method is recommended for lawns badly infested with dandelions. Reseeding of the lawn is advised as a supplementary measure.

During 1914, Arthur reported that, in Indiana, on one area sprayed with iron sulfate four times in 1913 and three times in 1914, most of the dandelions were killed, but that they again appeared during the next three months and later became quite abundant. On another area, sprayed four times during 1914, approximately one-half of the dandelions were killed. After-treatment measures, in the form of liming the soil and reseeding with blue grass seed, were used in these experiments.

In a recent and very complete bulletin, Longyear (1918) discussed the life history of the dandelion and some methods of eradication used in Colorado. This experimenter concludes that there is no easy, certain method of exterminating the dandelion or of holding it in check for any considerable length of time. However, it may be kept under control by persistently employing one or more of the following methods: (a) careful establishment of the lawn and later heavy reseeding; (b) applying a small amount of gasoline or kerosene to the crown of each individual plant; (c) deep digging of the entire plant; (d) prevention of seed production on the premises; and (e) by spraying infested lawns with a solution of iron sulfate. The last-named method, labor costs considered, proved to be the cheapest and most effective method of eradicating dandelions.

THE DANDELION.

SPECIES.

In New York lawns the common dandelion (*Taraxacum officinale* Weber) with its showy flowers and ragged, mussy foliage is the one generally found. However, the red-seeded dandelion (*T. erythrospermum* Andrz.) occurs occasionally. The red-seeded dandelion is readily distinguished from the common dandelion by its smaller, sulphur-yellow heads, glaucous bracts, more finely cut leaves and bright red or red-brown seeds with very fine grayish-white pappus. The common dandelion has orange-yellow heads, coarsely pinnatifid and bluntly lanceolate leaves, and olive-green or brownish seeds with short hard points. In both species, when the blossom appears, the double row of bracts which encloses the many-flowered head spreads apart and exposes them. The inner involucre closes after blossoming, and the slender beak of each flower elongates and raises the pappus of capillary bristles while the fruit is forming. The whole involucre, which is a double row of bracts, is then reflexed, exposing the nearly mature naked achenes or fruits with the pappus in an open globular head ready to be widely distributed by the wind.

PROPAGATION.

The dandelion is propagated by seeds. However, when once it has gained possession of the soil it will hold on to it persistently, perpetuating itself by heavy seeding, and also by its large, thick, fleshy, deeply-penetrating roots which resist occasional cutting by sending up new sprouts as discussed later in this bulletin.

PARTHENOGENESIS AND SEED PRODUCTION.

Seed production is an important phase in the life history of the dandelion since it is the one important means of distribution of the plant. At the outset of the work with dandelion eradication a study of the problem of seed production was started. The belief seems to be quite generally prevalent that the transfer of pollen from the stamens to the stigma of the pistil is necessary before seeds can be produced on the dandelion. However, in the common dandelion (*Taraxacum officinale*), at least, pollination is not only unnecessary, but may be, perhaps, altogether unimportant as a factor in seed production. Evidently, parthenogenesis, or apagamous development of the embryo, occurs in this species. As early as 1903, Raunkiaer performed some experiments on several forms of *Taraxacum* by employing a method of castration in which both anthers and stigmas of unopened buds were sliced off with a sharp knife. From the results of his work he announced that dandelions in Denmark are parthenogenetic; that is, they produce fruit freely without fertilization. Juel (1904), and later, Murbeck (1904), followed up the work of Raunkiaer with careful cytological investigations of the tetrad formation in the ovule, and found that parthenogenesis does occur in the genus *Taraxacum*. Murbeck studied *Taraxacum vulgare* which produces abundant, but imperfect pollen, and *T. speciosum* which produces no pollen at all. However, Dahlstedt (1904) stated that, in Belgium, there are two or three species of *Taraxacum* in which pollination seems necessary. Schkorbatow (1910), as a result of his studies of parthenogenesis in the genus *Taraxacum*, stated that the removal of the anthers of the flowers does not in any way affect the germination of the seeds. According to Ikeno (1910), Handel-Mazzetti, in a monograph of the genus *Taraxacum*, states that hybrids appear among the species of the genus. Therefore, normal fertilization may be expected among certain species of *Taraxacum*. Ikeno (1910) also reported that K. Tanaka, in unpublished results of some work done in Japan during 1908 and 1909 in which Raunkiaer's castration method was used, stated that *T. albidum* formed seeds parthenogenetically while *T. platycarpum* did not. Later investigations by Ikeno confirmed Tanaka's findings in that *T. platycarpum* does not form seeds parthenogenetically, while in other forms of *Taraxacum* both normal fertilization and parthenogenesis occur.

All of the experiments and studies concerning seed production made by the writer and herewith reported were made with *Taraxacum officinale* Weber. During the month of May, in the years 1914 and 1915, a number of dandelion buds were enveloped within parchment paper sacks just before they opened. At the time the heads on the same and adjoining plants had produced seeds the sacks were removed. Seeds apparently normal in size, color, and all other respects were formed on the heads enveloped within the sacks, indicating that parthenogenesis, cross-fertilization between flowers of the same head, or self-fertilization had occurred. Some experiments designed to test the effect of pollen from other dandelion flowers yielded inconclusive results, tho giving some indication that fertilization with pollen may occur.

On May 26, 1919, a considerable number of dandelion plants which still held unopened buds were located. With a sharp razor the stamens and pistils together with the upper portion of the two sets of green bracts were sliced off as close as possible to the ovary, and then the head was enclosed in a parchment paper envelope which was secured upright to a stake driven beside the plant. After a number of plants were treated in this manner a series of buds were castrated in like manner and left uncovered; that is, they were not enclosed in envelopes. On June 5 both the bagged and unbagged heads had produced seeds. The seeds from each head were collected in separate bags and later (on June 11) placed in a germination chamber along with separate lots of seeds from adjoining untreated seedhheads which served as checks. The germination tests of these seeds were made by placing them between sheets of blue blotting paper in a germination chamber maintained at a temperature of 20° C. for the first 18 hours and 30° C. for the remaining six hours of each day. The results of a single test will be given here. They are as follows:

Table 1. Results of Germination Tests of Seeds from Castrated and Uncastrated Dandelion Flowers.

Date.	Number of Seeds Germinated.		
	Flowers castrated and bagged.	Flowers castrated but not bagged.	Check.
June 11 Test started			
June 17	5	1	4
June 19	18	1	5
June 23	13	0	1
June 26	6	0	1
June 30	44	14	24
July 5	11	4	11
July 9	5	1	9
July 14	39	19	33
July 19	58	50	55
July 21	10	3	9
Total number germinated	209	93	152
Total number not germinated	761	73	62
Total number tested	970	166	214
Percentage germinated	21	56	71

From the results of these tests it seems quite evident that parthenogenesis does occur in *Taraxacum officinale.* This conclusion is in accord with the evidence produced first by Raunkiaer and later by other investigators. Also, it appears that a certain amount of normal fertilization may occur if one is to base judgment upon the difference in germination percentage between the seeds of check plants and those of unbagged castrated flowers. The lower germination of seeds from bagged flowers as compared with unbagged, castrated flowers may have been due to certain factors or abnormal conditions resulting from bagging.

GERMINATION OF THE SEED.

In germination tests of dandelion seeds collected from lawns it was found that some of the seeds were matured sufficiently to germinate as soon as they begun to leave the plant; and the percentage of germination increased directly in proportion to the degree of maturity. Flower heads cut off with a lawn mower immediately after blossoming failed to produce seeds capable of germination. Therefore it seems safe to conclude that a lawn clipped regularly and at least once a week will not be a source of contamination for clean lawns in the neighborhood. However, some seed heads which lie close to the ground escape the mower blades. These must be removed by hand picking or with a dandelion rake if seed formation is to be entirely prevented.

In the germination tests of the seeds used in the study of parthenogenesis it was found that a quicker response was secured when the range of temperature was greater than that ordinarily used, *i.e.*, when the temperature was permitted to rise to 38° C. for a very short time. Also, it was found advisable to place a small piece of folded blotting paper along with the seeds between the folds of paper to facilitate aeration.

DANDELION ERADICATION EXPERIMENTS.

ERADICATION EXPERIMENTS AT THIS STATION PRIOR TO 1912.

The results of lawn spraying experiments conducted by French (1911), while showing the iron sulfate treatment to be partially successful, did not seem to warrant its recommendation as a practicable method of control. A strip of lawn was sprayed six times during each of two successive seasons, using, the first season, 1.5 pounds, and the second season, 2 pounds of iron sulfate in each gallon of water. While this treatment prevented blooming of the dandelions, and even killed many of the plants, a considerable number remained alive when the experiments were necessarily discontinued at the middle of the second season because of severe injury to the grass. Apparently, the stronger solution used the second season caused considerable injury to the grass as mid-summer approached and the rate of growth of the grass decreased owing to unfavorable weather conditions. In summarizing the results of his experiments with iron sulfate solution, French stated that it was not clear why dandelion spraying should fail in New York when it had been successful elsewhere. He further stated that "the failure of the treatment seemed to be due to the great vitality of the dandelion roots." In an attempt to throw some light upon the question of the vitality of the dandelion roots French removed the tops from two plants by cutting just below the crown. This was done successively as soon as new leaves had unfolded for eight times when both plants succumbed to the treatment. French reasoned from these results that if dandelions could withstand six or seven cuttings they could survive as many sprayings, or possibly more, since spraying did not remove the tops as completely as did the cutting.

THE EXPERIMENT IN 1912.

Since the experiments of 1909 and 1910 had not met with the success which seemed to be characteristic of the trials with iron sulfate on dandelions conducted elsewhere, it was deemed advisable to give the method a further test. Work was continued this year by laying off a plat 15 feet wide and 100 feet long in an old lawn which was well sodded over with Kentucky blue grass and red top grass, but badly infested with dandelion plants. This lawn was on a clay loam soil and in all particulars typical of the average lawn in this state.

This strip of lawn was sprayed with iron sulfate seven times during the season and at the rate of approximately 100 gallons per acre, slightly over four gallons of the solution being used on 1500 square feet at each application. The spray solution was applied with a compressed-air sprayer and contained one and one-half pounds of iron sulfate to each gallon of water. The spray was applied at intervals of three weeks for the first three months, or during the vigorous growing season, and approximately once per month during the remainder of the season. The last spraying was made on September 20. The first spraying was made on May 4, at a time when the first blossom heads were opening. After each application of the solution the grass in the sprayed area was badly blackened, and remained unsightly for several days. It was noted, however, that the weather conditions at the time of the application had considerable to do with the extent of blackening and the period of time which elapsed before the normal appearance of the lawn was regained. The blackening of the grass was more marked and was retained longer following the sprayings made in the mid-summer months when periods of dry weather prevailed. It was during these periods when the severest injury to the tips of the grass leaves occurred.

Shortly following the fifth spraying, made late in July, it was noted that the grass in the sprayed area showed a darker green color than did the adjoining unsprayed lawn. This darker green color appeared to be cumulative as the season advanced. At the time of the last spraying, September 20, the sprayed area was very clearly distinguished by the darker green color of the grass (Plate I, fig. 1), also there were but few living dandelion plants remaining in the plat. The final spraying for the season killed the foliage on all the dandelion plants in the sprayed area to such an extent that less than thirty plants showed any green foliage when the fall season came to a close. As far as the killing of the dandelion plants was concerned, the experiment was a decided success. Experience seemed to indicate that five sprayings or, possibly, fewer would have secured the same results. The sprayings which could well have been omitted were those made during the latter part of July and in August.

THE EXPERIMENTS IN 1913.

PLAT 1.

In the spring of this year, at the active blooming period, the clear sod of the sprayed area of this plat presented a marked contrast to the adjoining untreated area which contained countless numbers of dandelion plants in bloom (Plate I, fig. 2; also Plate II).

The eradication of the dandelion plants in this plat was so complete that it was unnecessary to spray this season. However, it was evident that the bare spots left by the dead dandelions would soon be reoccupied by other dandelions from seeds unless something were done to prevent it. Clearly, the advantage gained by spraying should be followed up next spring by reseeding with grass seed to cover the bare spots before dandelions could take possession of them. Also, it was evident that the lawn grasses had been slightly injured leaving some of the coarse weed grasses, such as crab grass, more in evidence.

During this season various tests in the form of after-treatment measures were conducted, having in view the hastening of the healing of the scars left by the dead weeds, and the renovation of the turf. These treatments consisted of the use of fertilizers alone, seed alone, and combinations of fertilizer and seed upon sections of lawn

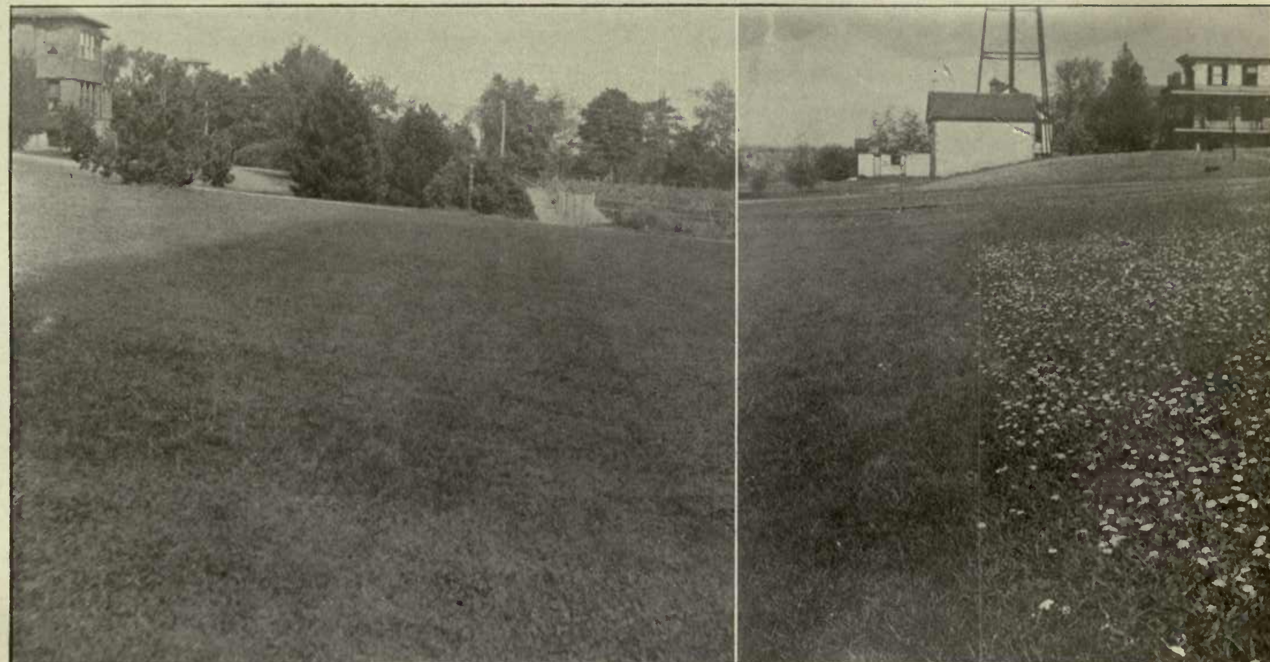

Fig. 1. Fig. 2.

Plate I.— Effect of Iron Sulfate Spray upon Grass and Dandelions.

Fig. 1. Showing darker green color of grass on the sprayed area.

Fig. 2. Showing contrast between clear sod of sprayed plat (left) as compared with the unsprayed lawn. Plat 1, 1913.

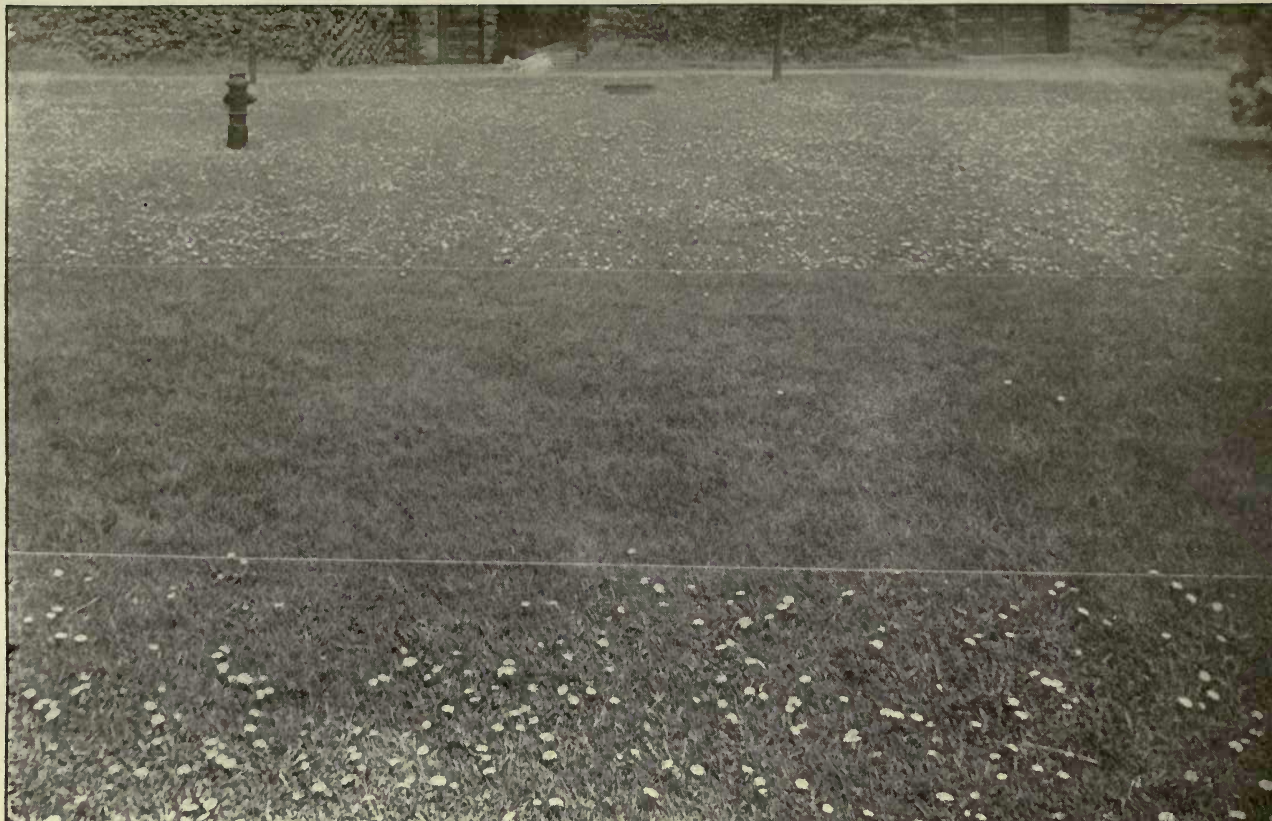

Plate II.— Dandelion Spraying Experiment.

Appearance of Plat 1 (center) in May, 1913, one year after spraying.

(25x45 ft.) which included both sprayed and unsprayed areas. The following diagram shows the arrangement and treatment of the different sections.

Section: A	B		C	D
Bonemeal	Seed alone.	Unsprayed.	Check.	Stable
and	Seed alone.	Sprayed.	No treatment.	manure and
seed.	Seed alone.	Unsprayed.		seed.

DIAGRAM 1. ARRANGEMENT AND TREATMENT OF SECTIONS IN EXPERIMENT ON AFTER-TREATMENT OF LAWN SPRAYED WITH IRON SULFATE FOR DANDELIONS.

Section A was treated twice during the season (March 29 and October 16) with fine-ground bonemeal at the rate of 1000 pounds per acre.

Section D was given an application of stable manure in December, 1912. This was allowed to remain on the ground over winter and the coarse material raked off late in March, 1913.

On Sections B and C no fertilizer of any kind was used. Sections A, B and D were given a generous reseeding with a seed mixture containing 11.5 pounds of Kentucky blue grass and 8.5 pounds of red top. This amount (20 pounds) allowed 25.8 ounces of seed per square rod of lawn. On April 4, and just before sowing the seed, the four sections were raked over thoroly with an iron rake. After the seed was sown Sections A and B were sprinkled with a light covering of compost soil. The entire area (all four sections) was then rolled with a heavy lawn roller to counteract the "frost lift," and firm the soil about the roots of the grass.

With reference to the results obtained from the after-treatment measures, it was recorded on May 13, 1913, that the application of manure on Section D had retarded, by about two weeks, the blossoming of the dandelions in the unsprayed area. However, both dandelions and grass made a vigorous growth. Early in July note was made of the fact that, in the sections reseeded, all of the bare spots left by dandelions killed by spraying, were well covered with a growth of young grass plants. The effect of the application of bonemeal on Section A was not evident until early in September when the darker green color of the grass in this entire section became noticeable.

PLAT 2.

Plat 2, on the Station grounds, was staked out early in the spring of 1913. It consisted of an area 15 x 100 feet located north of the Station horse barn, and it crossed, at right angles, the plat sprayed by French in 1909 and 1910. The soil was a clay loam lower in fertility and more responsive to the effects of drought than the soil of plat 1. Like many other soils immediately surrounding dwellings, this soil had been modified by building operations in the past. This lawn was selected because it was believed to be typical in many respects of the average dandelion-infested lawn in this State. The plat selected as well as the adjoining lawn on all sides was badly infested with dandelions. Scarcely a square foot of area could be found which did not contain at least two or three vigorous plants.

This plat was sprayed six times during the season with four gallons of solution made by dissolving one and one-half pounds of the "sugar" form of iron sulfate in each gallon of water. This quantity of solution was found sufficient to cover the area thoroly. After each application the sprayed plat presented the usual black, unsightly appearance which disappeared after a few days.

As midsummer approached it became increasingly evident that this lawn, because of the unthrifty condition of the grass due to low fertility of the soil, would not withstand spraying during the dry midsummer months without some special care in the form of watering and fertilizing. Nitrate of soda has been recommended as a desirable application to induce the growth of grass during the summer months. In order to test the value of this fertilizer in connection with the response desired from spray-injured or blackened lawns, nitrate of soda was applied at the rate of 100 pounds per acre to the west one-half of this plat. For this area (15 x 20 feet) two pounds of the nitrate of soda was dissolved in a large volume of water which was then sprinkled over the lawn with a sprinkling can. Two appli-

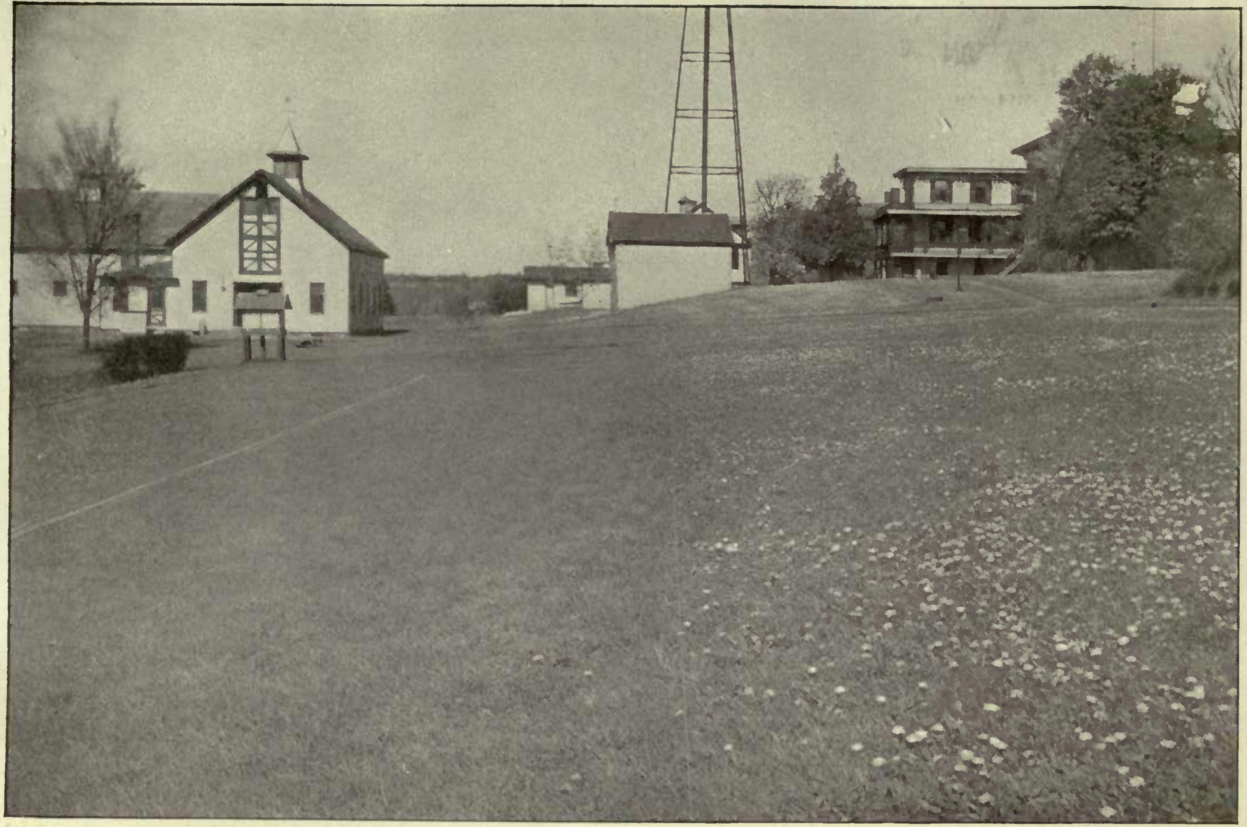

PLATE III.— DANDELION SPRAYING EXPERIMENT.

Appearance of Plat 1 (left center) in May, 1914, two years after spraying.

Plate IV.— Dandelion Spraying Experiment.

Appearance of Plat 2 (right) in May, 1914, one year after spraying. Compare Plate II.

cations were made — one on May 24, the other on July 18. The effect of this treatment showed rather promptly in the darker green color of the grass. It prevented, to a certain extent, the brown, parched appearance of the lawn during the months of July and August.

At the time of the last spraying of the season (October 4) there were a considerable number of dandelion plants scattered over the sprayed area. These were nearly all killed by the spraying, tho a few retained some green leaves and gradually recovered, going into the winter with some foliage.

As far as eradication of the dandelions is concerned, the results with this plat were not as marked or as complete as with Plat 1 which was located on a somewhat more fertile soil. The writer believes this to be due to the dry season, the vigorous condition of the dandelion plants (most of them being old and quite large), and the low fertility of the soil which did not give a quick growth to the grass, and cause it to come in where the dandelions were killed out.

THE EXPERIMENTS IN 1914.

PLAT 1.

At the beginning of this season (on May 7, two years after spraying) a count of the dandelion plants showed only twenty-seven in bloom (Plate III); while the adjoining lawns were golden yellow with blossoms and later white with many fluffy gray seed heads, which served as a great source of infestation for the sprayed area. The result of this infestation was apparent in late summer when it was noticed that a number of young seedling dandelion plants were appearing in the sprayed area. On October 17, at practically the close of the growing season, it was noted that the outlines of the sprayed area were plainly discernible at a considerable distance because of the small number of dandelions present. By the average person this area would be classed as a " clean lawn." Section A, treated with bonemeal during 1913, was still plainly outlined by the slightly greener color of the grass.

PLAT 2.

Plat 2, which was sprayed six times during the previous growing season, showed quite a number of dandelions in bloom (Plate IV).

A little later in the spring both of the sprayed plats were plainly distinguishable by the darker green color of the grass, and, in certain areas, by its much larger size. This condition was quote noticeable in the case of Plat 1. The lawns adjoining Plat 2 were badly infested with dandelions. The previous season's experience with this particular plat plainly indicated that on a poor soil with a thin stand of grass and many old, vigorous dandelion plants, attempts to completely eradicate the pest by spraying alone might not be entirely successful. It was apparent that some additional treatment, such as fertilizing and reseeding, should be given the sprayed areas. It was, therefore, deemed advisable to spray this plat for another season and supplement spraying with the above-mentioned after-treatment measures. Accordingly, the dandelions were "sprayed off" at the same time that Plat 3, immediately adjoining, was sprayed. By the term "sprayed off" it is meant that the area was gone over and sprayed with iron sulfate solution only where there were dandelion plants.

PLAT 3.

Plat 3, size 15 x 100 feet, was located so that it immediately adjoined Plat 2 on the north. This plat was badly infested with dandelions, and contained other weeds such as narrow-leaved plantain, mallow, knot grass, and a small patch of wild geranium or cranesbill. By combining Plats 2 and 3, an area 30 x 100 feet was made available for spraying. Beginning May 7, these combined plats were sprayed six times during the season with a solution containing one and one-half pounds of iron sulfate to each gallon. Four gallons of the iron sulfate solution were used at each application. Shortly following the first spraying it was very noticeable that all of the dandelion foliage was killed. However, there were a few plants which were blossoming. The sprayed plats, with these few blossoms, presented a marked contrast to the adjoining unsprayed lawns which were yellow with blossoms (Plate V). An observation made during the previous two seasons was again substantiated; namely, that a thoro application of iron sulfate solution early in the spring, when the first central buds are forming and about ready to open, will entirely prevent blossoming and seed formation.

Blackening of the grass followed every application, and the dandelion foliage was killed down. By the end of the season the plats

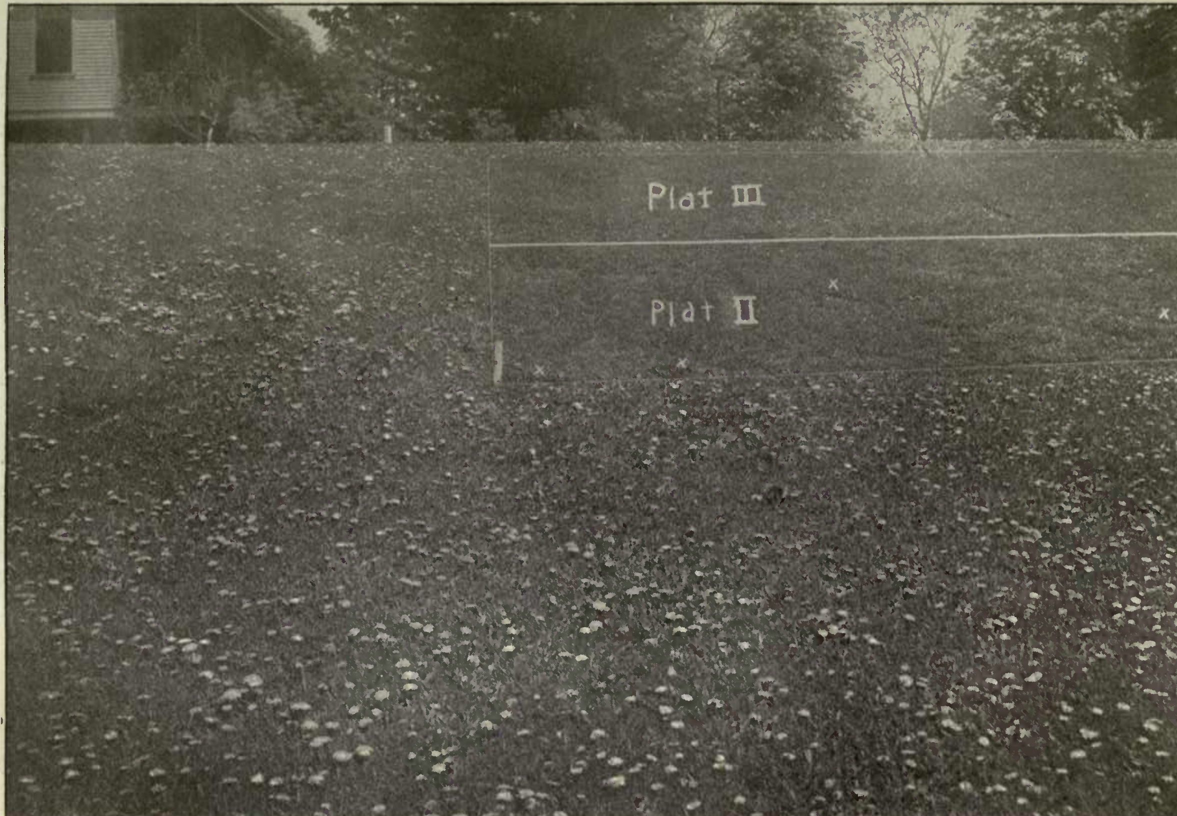

PLATE V.— DANDELION SPRAYING EXPERIMENT.

Appearance of Plats 2 and 3 after the first spraying in spring of 1914. The cross marks (X) indicate the location of typical bare spots left by dandelions killed by spraying during 1913.

Plate VI.— Dandelion Spraying Experiment.

Appearance, in 1915, of Plats 2 (center) and 3 (right) two and one years, respectively, after the first spraying. Note the black streaking resulting from and immediately following " spraying off " dandelions in the spring of 1915.

were nearly free from dandelions. Late in the summer, when rains were more frequent, the sprayed plats took on a darker green color and presented a much healthier and more pleasing appearance than the adjoining unsprayed lawns with the rough, mussy dandelion foliage. Weeds, such as mallow, purslane, dock, and narrow-leaved plantain, which are not as easily killed by the iron sulfate, appeared in the spots where the large dandelions were killed out.

THE EXPERIMENTS IN 1915.

PLAT 1.

On May 7, 1915, three years after this plat was first sprayed, there were only a few (less than 30) dandelion plants in bloom. However, there were quite a number of young seedling plants appearing over the entire plat. At the close of this season, following frequent rains, there were approximately one-fourth as many dandelions in this sprayed area as in the adjoining unsprayed lawn. These plants were mostly young seedlings, and undoubtedly came from wind-blown seeds from plants which seeded heavily in adjoining lawns.

The experiment to date shows quite conclusively that the dandelions can be killed during one season's careful spraying, but that the plants may reappear in the lawn from seeds which are constantly "blowing in" from nearby lawns where the pest is permitted to produce seeds.

PLATS 2 AND 3.

In the spring of 1915 there were comparatively few dandelion plants (less than 100 in the two plats) which blossomed. These presented a marked contrast to the profuse blossoming of innumerable plants in the adjoining unsprayed lawns (Plate VI). The dandelion plants remaining in the unsprayed plats were single plants, many of them being seedlings. The grass in the sprayed plats showed no injurious effects of the iron sulfate while, on the other hand, it possessed a much greener color than the grass in adjoining areas. In actual practice these sprayed lawn areas would be considered "clean" by the average person, and would receive no special attention.

It was noted at the close of the previous season that certain lawn weeds other than the dandelions were appearing in the bare spots where the latter had been killed out. Some of these bare spots in the turf were several inches in diameter (Plate V). It was because of the presence of these weeds and the few remaining dandelions that these two plats were again combined and "sprayed off" four times during the season with the iron sulfate solution, using one and one-half pounds of sulfate to each gallon of water. No attempt was made to spray the entire area of the two plats, only the dandelion plants and other weeds being sprayed. The usual blackening of of the grass followed each spraying, but disappeared after a short time. However, this "spraying off" method has the disadvantage of leaving the lawn streaked or spotted with black for a few days (See Plate VI). At the time of the third spraying (July 10) it was noted that all of the old dandelions had been killed; but quite a number of young plants were appearing just within the border of the plats. Nearly all of these young plants were within three feet of the border of the sprayed plats, and apparently came from seeds of dandelion plants in the unsprayed lawn adjoining. Following the third spraying, in July, it was observed that because of favorable weather conditions the spray solution was particularly effective in killing the foliage of the weeds. All of the dandelion and narrow-leaved plantain foliage was killed. The foliage of broad-leaved plantain was badly injured. The patch of cranesbill or wild geranium located in Plat 3, also showed serious foliage injury.

During the latter part of the season rains were frequent, causing a vigorous growth of grass, and also forcing the growth of a number of seedling dandelion plants in the sprayed area. The sprayed area, with its darker green grass, presented a much more even and pleasing appearance than did the adjoining unsprayed lawn where the dandelion plants were very thick.

AFTER-TREATMENT OR RENOVATION MEASURES ON PLATS 2 AND 3.

Methods of renovation or after-treatment were started on April 4. Plats 2 and 3 were divided crosswise into four sections or areas each 25 x 30 feet. The following diagram shows the location and treatment accorded each section.

Section A was retained as a check. No treatment.

Section B was treated with 40 pounds of a complete fertilizer having a composition of 3–10–12.

Section C was treated with 50 pounds of ground limestone.

Section D was reseeded with a mixture of equal parts of Kentucky blue grass and red top grass seed which was carefully raked in with a garden rake, especial attention being given to the bare spots in the turf.

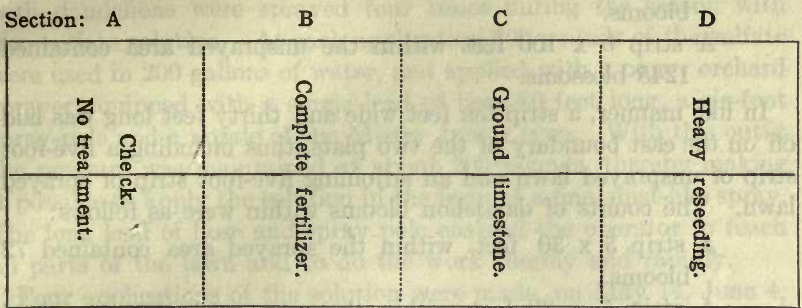

Diagram 2. Arrangement and Treatment of the Four Sections of Plats 2 and 3 in Experiment on After-treatment of Lawn Sprayed with Iron Sulfate Solution.

Results of the after-treatment measures were first evident forty days later when the section treated with complete fertilizer was found to be plainly outlined because of the distinctly larger size and darker green color of the grass. The growth of the grass had a tendency to cover up bare spots left by dead weeds. No noticeable results, during this season, came from the use of the ground limestone. In Section D, which was reseeded, there was a satisfactory growth of young grass plants. However, it was about ten weeks before the dead-weed scars in the turf were completely healed over.

THE EXPERIMENTS IN 1916.

In the spring of this year, at the time of the first profuse blooming, the sprayed plats were readily discernible at a distance by the small number of dandelion blossoms as compared with the unsprayed portion of the lawn. The stakes which originally marked the corners of the plats were easily located by laying lines around the border as indicated by the dandelion blossoms. Where the end lines crossed the side lines the corner stakes were found imbedded in the turf.

In order to measure the difference in number of dandelions and express it in numerical terms, a strip ten feet wide was laid off along the entire south boundary of the plats. This area was so located as to include a strip five feet wide by 100 feet long on both the sprayed and the unsprayed lawn. The dandelion blooms were then carefully counted in each strip. The results are as follows:

A strip 5 x 100 feet within the sprayed area contained 140 blooms.

A strip 5 x 100 feet within the unsprayed area contained 1245 blossoms.

In like manner, a strip ten feet wide and thirty feet long was laid off on the east boundary of the two plats, thus including a five-foot strip of unsprayed lawn and an adjoining five-foot strip of sprayed lawn. The counts of dandelion blooms within were as follows:

A strip 5 x 30 feet within the sprayed area contained 72 blooms.

A strip 5 x 30 feet within the unsprayed area contained 628 blooms.

As regards the effectiveness of the spraying, the above figures show that there were approximately 89 per ct. fewer dandelion blooms in the sprayed area. Apparently, the two or three season's spraying on Plats 3 and 2, respectively, had reduced the number of plants 89 per ct. None of the plants remaining on the sprayed area had as yet produced seeds.

THE EXPERIMENTS IN 1917.

CONDITION OF PLAT 1.

At the beginning of this season, five years after spraying, there appeared to be fully as many dandelion plants in the sprayed plat as in the adjoining areas, with the exception of the western section of the plat which was treated with manure in 1913. Here, the effect of the manuring had, apparently, been in the direction of causing a vigorous growth of grass which prevented the reappearance of seedling dandelion plants.

CONDITION OF PLATS 2 AND 3.

On these two plats there were fewer dandelions than on the adjoining unsprayed lawn. However, seedling dandelions were appearing in constantly increasing numbers.

SPRAYING LAWNS WITH A POWER SPRAYER — PLAT 4.

Even tho the work of the previous years with a small outfit on small plats had been comparatively successful, it seemed advisable to supplement it with a more extensive trial on larger areas with a power sprayer. Accordingly, six areas of the Station lawn located between walks, drives and buildings, and which were badly infested with dandelions were sprayed four times during the season with iron sulfate solution. At each application 300 pounds of the sulfate were used in 200 gallons of water, and applied with a power orchard sprayer equipped with a single lead of hose 80 feet long, a six-foot spray-pole and a nozzle of the Mistry Junior type. With this outfit the pressure was maintained at about 200 pounds, thereby making it possible to apply the solution in the form of a fine, mist-like spray. The long lead of hose and spray pole enabled the operator to reach all parts of the lawn and to do the work thoroly and rapidly.

Four applications of the solution were made, on May 14, June 4, June 28 and July 26. Owing to the fact that the power sprayer was no longer available for this work, the spraying was discontinued in July after the fourth application. Judging from the results obtained in the smaller experiments, later applications would have been desirable and undoubtedly would have increased the effectiveness of the treatment.

The results obtained from the use of the power outfit were similar to those obtained with hand sprayers. The grass was somewhat blackened after each application. The dandelion foliage was quite effectively killed, altho a large number of plants recovered after each application and made a growth of leaves three to four inches long before the next application was made.

Shortly following the first application there was a marked contrast in appearance between the sprayed lawns and some unsprayed lawns nearby. On the unsprayed lawns countless dandelions blossomed and formed seeds which were scattered widely by the wind. The sprayed lawns showed practically no blossoming dandelions and only an occasional large plant still living. Following the fourth spraying, made July 26, and at a time when the lawn soil was comparatively dry, the lawn grasses were badly blackened, and in some places severely injured. This injury to the grass is believed to have been due partly to the dry condition of the soil, and partly to the influence of the light shower which fell during the evening of the day the solution was applied. This experience confirms a previous conclusion, namely, that lawns should not be sprayed with iron sulfate during the hot dry weather of July and August when the lawn soil is dry.

PLAT 5.— THE ROBINSON LAWN.

This test was made on the lawn of Mr. R. H. Robinson in the city of Geneva, which represented well the average lawn surrounding a city residence. The turf, composed of Kentucky blue grass and some red top, was quite badly infested with dandelions. This lawn was sprayed four times during the season of 1915. A barrel sprayer mounted on wheels and equipped with a long lead of hose was used, and the solution was made by dissolving one and one-half pounds of iron sulfate in each gallon of water.

The results of the treatment were very similar to those obtained on the Station grounds. The early blossoming of the dandelions was prevented, and nearly all of the dandelions were killed. The grasses suffered no permanent injury.

One application of the solution was made July 31 when the soil was quite dry. Following this spraying there was quite serious blackening and scorching of the grass in certain spots where the soil was dry and the solution applied in liberal quantities. This experience agrees with a previous one on the Station lawn in which it was clearly demonstrated that lawns should not be sprayed during the dry summer months when both the grass and the soil lacked moisture. Also, some care should be exercised to prevent drenching of the grass since injury to the crowns of the plants may result.

At the end of the season, this lawn showed approximately three per ct. of the original number of dandelion plants, and none had blossomed or formed seeds. This season's test was considered to be successful.

THE EXPERIMENTS IN 1918.

PLAT 1.

This strip of lawn, five years after spraying, had no appearance of any kind which would aid in determining its location. Some white clover and yellow trefoil had reappeared in the plat, and it was well infested with dandelions. There were as many dandelions in this plat as in the adjoining lawns; but it is safe to say that they were younger plants, the leaves being smaller, more nearly erect, and in more compact clusters.

PLATS 2 AND 3.

These plats were in no particular to be distinguished from adjoining lawns. Apparently, they contained as many dandelions. Plants of narrow-leaved plantain, also some patches of white clover and yellow trefoil were to be found scattered over both plats as well as in the adjoining lawn. With the exception of Section D, which was reseeded with grass seed, the condition of these plats plainly emphasized the great need of after-treatment measures to follow the spraying.

PLAT 4.

The appearance of the lawns included in this plat, one year after the first spraying with the power sprayer, gave unmistakable evidence that the extent of blossoming had been very materially reduced. A large majority of the old plants had been killed. Nevertheless, there were many young plants in certain parts of the sprayed area. In the light of previous experience it was plainly evident that the spraying operations on this plat were discontinued too early in the season to derive the greatest benefit from the treatment. Certainly, the plants should have been forced into the winter without foliage.

PLAT 5. THE ROBINSON LAWN.

In the spring of 1918 a small number of dandelion plants were forming blossom buds, and several had blossomed when the owner made an application of the spray solution. Blooming was thereby prevented and, so far as could be determined, there was no increase in the number of dandelions present in the lawn this season.

THE EXPERIMENTS IN 1919.

PLATS 1, 2 AND 3.

At the beginning of this season, seven, six and five years, respectively, from the time of the first spraying, it was plainly evident that there were as many dandelions in these sprayed plats as in the adjoining unsprayed lawns. It seemed to be plainly demonstrated that, where the sprayed lawns are adjoined by unsprayed lawns infested with dandelions, it will be necessary to resort to spraying about every third season in order to keep dandelions under control.

PLAT 4.

In June of this season, two years after spraying, it was obvious that, in certain restricted areas adjoining buildings or sheltered by shrubbery, the old dandelion plants had been killed out; only an occasional seedling plant could be found. However, in the greater part of this lawn area, sprayed four times with the power sprayer, there were as many dandelions as in adjoining unsprayed lawns. But it should be stated that the dandelions in the sprayed area were mainly young seedling plants.

PLAT 5. THE ROBINSON LAWN.

The owner of this lawn decided to spray, in 1919, only restricted areas on which the dandelions blossomed. It was unnecessary to spray the entire lawn. This lawn, being in fairly good condition at the outset of the test, responded well to the treatment by filling in the bare places with a growth of grass. It is believed by the writer that heavy reseeding would have been advantageous in this instance, and would have hastened the thickening of the stand of grass. The behavior of this lawn, bordered on both sides by lawns producing dandelion seeds, seemed to demonstrate that, on the average lawn similarly situated, three or four sprayings during the season with iron sulfate applied carefully and at the proper time will practically control the dandelion pest for a period of from two to three years.

OTHER METHODS OF ERADICATION COMPARED WITH SPRAYING.

CUTTING.

Plainly, the problem of eradicating dandelions by cutting them out involves the question of the large amount of reserve food stored up in the root of the plant; also the fact that dandelion roots, when cut, callous over and produce a varying number of adventitious buds upon the upper end portion of the cut crown of the root.

As early as 1873, Caspary, followed by Warming in 1877 and by Wittrock in 1884, demonstrated that the dandelion (*Taraxacum officinale*) and certain other plants have the power to produce sprouts from adventitious buds on their roots when they are cut.

Hitchcock and Clothier (1898) and also Longyear (1918) have fully demonstrated that pieces of dandelion roots even an inch long may produce many new sprouts from adventitious buds on the cut crowns. The former writers found as many as fourteen new sprouts from a dandelion root cut off two inches below the surface of the soil.

Munson (1903) concluded from his study of the behavior of plants of two species of dandelions that, since every top or crown cut off may send up from one to six new plants, serious injury may occur to the lawn by materially multiplying the number of plants present, and also by frequently disturbing the turf by cutting.

Henderson (1905) also found that cutting off the plants below the ground with a spud only caused them to come up later.

Bolley (1908) stated that cutting tests upon old and young dandelions demonstrated that plants cut three to four inches below the surface readily send up new plants. He objected to the cutting process, also, because of the time and labor required for effective work, and because the turf is too much disturbed when really serious work is done.

At the outset of the work reported in this bulletin the writer had arrived at the conclusion that digging the dandelion from lawns when persistently followed and properly done, is quite effective in destroying large plants. However, it requires much time and patience, and often fails to kill more than a small percentage of the plants. Unless practically all of the root is removed the remaining portion will, in time, send up from one to several sprouts, with the result that the number of dandelions is increased rather than diminished.

In order to obtain more information regarding the behavior of dandelions after being cut, the following experiments were conducted: (1) In the spring of 1912, ten large dandelion plants on a rather unfertile clay soil were carefully marked with stakes. They were uniform in size, and each bore small flower stalks six to eight inches high. On May 18, when some of the flowers were in bloom and others past blooming, the plants were cut off just below the crown. Subsequently, these plants were cut off twice more during the season, the last cutting being made on August 16. None of them were killed. On the other hand, on October 30, at the end of the growing season, there were twenty plants instead of the original ten plants. Only one plant had remained single; all of the others had formed two or three plants from the cut crown. (2) In an attempt to ascertain the effect of deep cutting on dandelions growing under adverse conditions, twenty large plants were selected in a location where the soil was light in texture and quite dry during the greater part of the year. The plants were marked with stakes, and then cut off about three inches below the surface on April 26, 1915. On July 22, following a period of very dry weather which had prevailed since cutting, thirteen of the cut plants were dead. The other seven had made some growth. By September 1 only four of the twenty plants were alive. Apparently, the plants were killed at the outset by cutting them during dry weather. These results do not agree with those obtained in other tests on more favorable locations, and can be explained only by the fact that the soil upon which the plants grew was exceedingly dry, and the cutting was immediately followed by very dry weather. (3) Cutting plants in midsummer, or later, caused new growth at the expense of reserve food stored in the roots, and gave the best results by either killing the plants or weakening them.

CUTTING VS. SPRAYING DANDELIONS.

At this station, French (1911) concluded from his experiments and observation that spraying did not remove the leaves so completely from treated plants as did cutting, since plants which survived six or more cuttings could withstand as many sprayings and probably more. In order to obtain further data on this point, three experiments were conducted as follows:

Experiment 1. Ten pairs of dandelion plants of practically the same size, and growing within a foot of each other were selected. One plant of each pair was cut off below the crown, while the other plant was " sprayed off " with twenty per ct. iron sulfate solution. These plants were cut off and " sprayed off " on the same date five times during the season, the first treatment being given on May 3. Following each treatment, the " sprayed off " plants were the first to respond by making new growth. These plants usually made a growth of from three to five inches, and had four or five leaves before the cut-off plants were large enough to be again cut off. At the time of the third treatment, only one of the cut-off plants was alive, while four plants of the "sprayed-off" series were living, two of them having made a vigorous growth. At the time of the fourth treatment only two plants in the "sprayed-off" series were living. The foliage of these was again killed down by the sulfate solution. However, on October 3 of that year one of these plants was still living, and made some foliage which was " sprayed off " for the fifth time, after which it did not reappear. This experiment showed that in every case the " sprayed-off " plants were the last to succumb to the treatment, this indicating, in this case at least, that cutting is more effective than spraying.

Experiment 2. In another attempt to compare cutting and spraying, two adjoining plats, each containing 24 square feet, were treated simultaneously by spraying and cutting. On April 27, 187 plants were "sprayed off" in one plat and 100 plants were cut off in another. At the end of the season, October 6, just previous to the fourth treatment, there were 31 plants to be cut off, and 42 plants to be "sprayed off." Even tho the number of living plants in the two plats was about the same at the end of the season, it must be said that the cutting treatment was more satisfactory than spraying, due to the fact that some injury occurred to the grass on the sprayed plat following the spraying in August. In this test the work was necessarily done at a certain stage of the growth of the plants regardless of the weather conditions. Therefore, some injury occurred to the grass in the sprayed plat in August because of dry weather and a dry soil. In practice, such injury may be prevented by withholding spraying in dry weather.

Experiment 3. In another experiment, two adjoining plats, 3 x 6 feet and thickly infested with dandelions, were laid off on the lawn a few feet west of Plat 3 of the larger experiments. One of these plats was sprayed with twenty per ct. iron sulfate solution, and on the same day the dandelions in the other plat were cut off just below the crown. The two plats were treated six times during the season. The first treatment was made on May 6. On May 24, the date of the second treatment, 160 small dandelion plants were counted in the sprayed area, and 45 in the cut-off area. Here, again, following the first spraying, there was a quicker response of the sprayed dandelions than of the plants cut off. The following tabular statement summarizes the results of the various treatments:

	Number of Dandelions.	
	Sprayed Off.	Cut Off.
First spraying May 6	112	108
Second spraying May 24	160	45
Third spraying June 8	107	168
Fourth spraying July 1	96	141
Fifth spraying July 25	39	108
Sixth spraying August 16	25	125
On date of October 3 there remained	3	25

These results do not show a great difference in the rate or completeness of eradication accomplished by the two methods. However, it must be remembered in this connection that the cost of cutting the dandelions per square foot was considerably greater than for spraying them. During this experiment two cases were noted where spraying off had the same effect as cutting off the crown of the plant in that two to four plants started up from a single root where there was only one plant before. This is exceedingly common when plants are cut off or partially dug out.

THE USE OF GASOLINE AND KEROSENE ON DANDELIONS.

Of the various substances recommended as efficient herbicides, gasoline and kerosene are the most common.

Henderson (1905) treated dandelion plants by pouring brine, gasoline, and kerosene upon cut and uncut dandelions, and concluded that of the three substances used gasoline proved most efficient. The other two were not wholly efficient or caused injury to the grass at the point of application.

Olive (1909) treated dandelions by applying sulfuric acid, gasoline, and kerosene to the cut top of the crown. Sulfuric acid of twenty per ct. strength and kerosene were found to be effective. Gasoline, on the other hand, failed to kill the plants completely since the cut roots sprouted in two to three weeks.

Longyear (1918) concluded from his recent work with creosote, gasoline and kerosene that these are all effective herbicides, but that their use involves much time and expense, and some serious injury to the lawn may result where many dandelions are present.

In 1912, a number of large dandelion plants were selected and marked with stakes. By means of an oil-can a small quantity (one-half to one teaspoonful) of gasoline was squirted into the crown of each plant. Seven days later eighty per ct. of the plants were dead. Those which survived the treatment in time regained normal foliage.

In 1914, gasoline and kerosene were similarly applied to marked dandelion plants with the result that a high percentage of the plants were killed with one application. Kerosene proved to be nearly as effective as gasoline. However, the small spot of grass killed around each plant was larger in the case of kerosene than with gasoline, apparently because the kerosene did not evaporate as readily. A patented apparatus called a " dandelion gun " with which the plants were cut off below the crown and a small quantity of gasoline applied to the cut surface of the root was used with some success. This proved to be slow and expensive work when attempted on anything like a large scale.

The results of the work with these herbicides left but one conclusion, namely, that they are fairly effective, but the cost of application in time and material is relatively great. When a large number of dandelions are present in a lawn, the injury to the turf by the killing of the grass around each plant may be considerable in the aggregate.

OBSERVATIONS BEARING ON THE ACTION OF IRON SULFATE UPON THE LEAVES AND ROOTS OF DANDELION PLANTS.

At the outset, it was recognized that the action of the iron sulfate upon the dandelion foliage is a separate physiological problem requiring considerable study for its solution. This was not attempted in connection with the spraying experiments. However, some observations were made which are herewith presented. Soon after the solution was applied and the foliage began to dry off, the iron sulfate appeared on the plants as a whitish deposit. This was followed by the appearance of small drops of milky juice (latex) on the leaves and flower stalks. Longyear (1918) has recently suggested that this oozing of the latex is due to the absorption of the iron salt by the cells of the leaves and flower stalks, and the production of sufficient internal pressure or turgor to rupture the cell walls and liberate the latex. The writer's views accord with this explanation of the phenomenon. Shortly following the oozing of the latex, the foliage begins to blacken, first at the edges of the leaves and around points of injury. This blackening was invariably hastened by bright sunlight. However, it was noted in two cases that the killing of the plants was hastened by a period of cloudy, showery weather following the application of the sulfate in bright sunlight. Also, by heavy dew or a light shower during the first night after spraying. In addition to the withdrawal of moisture from the dandelion leaves there was plainly a chemical action of the iron sulfate upon the chlorophyll of the leaf whereby it was decomposed into a dark-colored substance scattered thru and within the leaf tissue. This action was observed to be more rapid when the application of the spray was made during warm weather following a period of rainy weather while the foliage was turgid. The sulfate solution may have a corrosive action upon the cell walls, since its effect was soon evident upon dead or yellowing tissue, injured tissue, and at the mutilated edges of the leaves.

In addition to the action upon the leaf tissue, it was found that, within a certain restricted area on Plat 5 (the Robinson lawn) where the solution at one time was applied too liberally, there was a very noticeable effect upon the crowns of the dandelion plants. Upon digging these plants, they were found to show more or less injury in the form of a decay of the upper portion of the crown. Often the decayed layer was one-half inch thick.

EFFECT OF IRON SULFATE SOLUTION UPON OTHER LAWN WEEDS.

During the progress of the work opportunity was afforded to observe the effect of the solution upon other lawn weeds. In a general way the results can be briefly stated as follows:

Common chickweed (*Stellaria media*) was killed after repeated sprayings.

Purslane (*Portulacca oleracea*) and yellow trefoil (*Medicago lupulina*) were killed.

Wild geranium or cranesbill (*Geranium Robertianum*) and mallow (*Malva rotundifolia*) were badly injured.

Heal all (*Prunella vulgaris*), gill-over-the-ground (*Nepeta hederacea*), broad-leaved plantain (*Plantago major*), curled dock (*Rumex crispus*), and narrow-leaved plantain (*Plantago lanceolata*) were either killed or badly injured.

Knot grass (*Polygonum aviculare*) and crab grass (*Digitaria humifusa*) were either uninjured or were slightly injured.

In the case of some of the weeds listed above, the extent to which they were injured depended upon their age and the thoroness with which they were sprayed. However, it must be remembered that drenching a lawn to kill the weeds may be followed by very severe injury to the grass.

Experience with lawn weeds such as chickweed, crab grass, dock, plantain and wild geranium emphasized the necessity of reseeding the lawn heavily after the last spraying in order to fill up the bare places in the turf where the clumps of dandelions were killed out. Nature appears to abhor bare places, especially in lawns, and often covers them with weeds.

EFFECT OF IRON SULFATE SOLUTION UPON LAWN GRASSES AND CLOVERS.

At the outset it should be stated that the clovers, including yellow trefoil and low hop clover (*Trifolium procumbens*), are killed by spraying with iron sulfate solution. No spraying with iron sulfate on lawns should be attempted unless the owner is willing to sacrifice, temporarily, the white clover (commonly called white dutch clover).

The first effect of the solution upon the lawn grasses is to cause a certain amount of blackening and discoloration immediately following each application. This discoloration lasts for only a few days, after which the grass regains its normal green color. Later, in our experiments, spraying was invariably followed by a more vigorous growth of the grass which was noticeable for at least a part of the first season following spraying, and, in one instance, during the second season. This better growth of the grass was invariably associated with a darker green color which was held during the entire season. The beneficial effect of iron sulfate solution upon grass has been observed and commented upon by other experimenters. Bolley (1909), in reporting it, mentions the fact that in North Dakota the iron sulfate solution had a very beneficial effect in the prevention of certain fungous diseases which attack blue grass.[1]

Aside from the temporary blackening, no serious injury to the grass occured except in one instance, mentioned elsewhere in this bulletin, when the spray solution was applied while the lawn soil was very dry; and in one other case when the solution was applied in too liberal quantity, causing some injury to the grass roots. Fortunately, both of these conditions can be readily avoided by selecting suitable periods for the spraying, and using care in applying the solution. Another form of injury, usually so slight as to be negligible, is that which occurs at the tips of leaf blades recently cut off by the mower or broken by excessive tramping.

TOXIC ACTION OF IRON SULFATE.

As regards the toxic action of iron sulfate upon the roots of dandelion plants in sprayed lawns, the writer will not venture an opinion since the experiments yielded no evidence upon this interesting point.

[1]In this connection it is interesting to note that, in some experiments made by Waite (1910), the addition of iron sulfate to self-boiled lime-sulfur solution sprayed on apple foliage caused the leaves to become darker green and hang on the trees longer.

On Plats 2 and 3, which received excessive quantities of the spray material, no injurious effect of iron sulfate in the soil was detected. In searching for an explanation of this matter, the writer is inclined to accept the view recently advanced by Longyear (1918), namely that iron sulfate is unlikely to produce an injurious effect on the roots of the plants since the chemical oxidizes very readily and, upon reaching the soil, is combined with soil constituents, and becomes insoluble and inert.

In this connection it is interesting to consider the killing of the clover by the sulfate in the light of the work of Ruprecht (1915), who found that sulfate of iron has a very harmful effect upon the roots of clover plants when used in excess of four parts per million in culture solutions.

At the Indiana Experiment Station, Arthur (1914, p. 35) did some work with red clover which led him to the conclusion that, when mixed with the soil, 400 pounds of iron sulfate per acre is the largest quantity which can be used without danger of injury to the clover.

RELATION OF WEATHER CONDITIONS TO EXTENT OF INJURY TO GRASS AND WEEDS.

Most experimenters recommend that the spraying be done on bright, dry days. In general, this appears to be true. However, according to our observation, there are certain exceptions to that rule. Apparently, the weather conditions preceding spraying and the condition of the lawn soil, whether wet or dry, are important factors. During eight years of observation we have found that serious injury to the grass may result if it is sprayed when the soil is dry. In such cases liberal spraying (drenching) materially increases the amount of injury which follows. Heavy dew following spraying was found to facilitate materially the action of the chemical and consequently increase the injury to the dandelions. It was found that, in certain instances, when the lawn was sprayed on a damp, cloudy day following a period of dry weather (Plat 4 sprayed July 28; and Plat 5, the Robinson lawn), the dandelion foliage was quickly and very effectively killed and the grass also displayed an unusual amount of discoloration. It was observed, too, that young seedlings of grass suffered more than older lawns. Bolley (1908, p. 551) has discussed a similar set of conditions encountered in his work in North Dakota on the eradication of weeds in grain fields.

In another instance spraying with the power sprayer was started on what promised to be a clear day. However, just as the job was finished it began to rain, and some rain fell during the evening of that day. The next day was again clear. It was noted that following this spraying the grass was badly blackened, and in some places quite severely injured. The foliage of narrow-leaved plantain and chickweed was almost completely killed by this application.

Our experience, then, teaches that during the greater part of the growing season when dandelions and grass are making a rapid growth, as in spring and fall, it is advisable to select, as a suitable time for spraying, a bright, clear, sunshiny day when there is but little wind and slight probability of rain for several hours. Also, that lawns should not be sprayed during periods of dry weather in mid-summer when the soil is dry and the lawn grasses are inactive. It seems certain that drenching of the turf with the spray solution should not be permitted at any time.

CONCLUSIONS AND RECOMMENDATIONS.

OUTLINE OF LAWN TREATMENT.

Eternal vigilance is the price of a good lawn free from weeds. The proper time to commence the fight against weeds is when the lawn is first made. Care should be taken to secure a thick, thrifty growth of grass at the start. Attempts to establish lawns on poor soil illy-prepared usually fail. After the lawn is established constant care is necessary to maintain it in a thrifty condition which will serve as a protection against weeds.

The measures most frequently used for the eradication of weeds from lawns are: (a) digging them out with a knife or spud; (b) heavy reseeding and fertilization to crowd them out; and (c) the use of chemical sprays to kill the foliage. The last-named method is the cheapest and as effective as any; but complete success requires the use of all three methods and some others.

The dandelion and certain other weeds may be eradicated from lawns, without injury to the grass, by proper spraying with iron sulfate solution. However, the weeds will soon return unless supplementary measures are employed. Unfortunately, there is no escape from the menace of dandelions seeding on adjacent grounds, because one has no control over the premises of his neighbors. Nevertheless, the occasional plants which survive spraying should be prevented from seeding by digging them out or by applying gasoline, kerosene, or dry iron sulfate to their crowns. The lawns should be mowed frequently, watered in dry weather, well fertilized, and bare spots reseeded. Whenever the dandelions reappear in considerable numbers it will be necessary to again resort to spraying.

CUTTING DANDELIONS.

Cutting off dandelions below the crown with a knife or spud is not only laborious but ineffective unless practically the entire root is removed or the foliage completely removed several times during the season, so that the plant has no opportunity to store up reserve food in the root. Shallow digging, unless done frequently, is worse than no digging because the root, when cut off, sends up from one to several new plants and the final result is a more profuse growth of dandelions. Deep digging, whereby practically the entire root is removed with a spud, stiff-bladed knife, asparagus knife, chisel, or other special tool, is recommended as a means of removing the few plants which survive spraying.

SPRAYING LAWNS.

Spraying with iron sulfate solution will usually prove effective when carefully, persistently and intelligently done.

NUMBER OF TREATMENTS AND TIME OF MAKING THEM.

Our experiments indicate that at least three (or, usually, five) thoro applications during a season are necessary to eradicate the dandelions from the average lawn in this state. To be the most effective, the spraying should be repeated as soon as the dandelion plant has regained new foliage and just before it is full grown — usually when the leaves are three or four inches long. This forces the plants to use up their reserve food stored in the roots, and eventually starves them. On the Station lawns, which were exposed to dandelion seeds from adjoining untreated lawns, it was found necessary to spray every second or third year, and to supplement the spraying with other control measures.

The time of application appears to be important. In our tests, the best results were secured when the first application was made in early spring after the central blossom buds were formed, but before blossoming. The first application should be followed by two or three later ones at intervals of three to four weeks during the spring growing season, and one or two others in late summer or fall. The last application should be made late enough in the summer or fall to prevent the plants from recovering before the close of the growing season.

A suitable day for spraying is one on which there is little wind and slight probability of rain for several hours. The sky may be either cloudy or clear. A heavy dew the following night is advantageous. Spraying should be discontinued during periods of drought in midsummer, when the grass is inactive and soil is very dry. Serious injury to the grass may result from spraying at such times. As far as possible, it should be arranged to spray two or three days after mowing and to mow two or three days after spraying.

STRENGTH AND QUANTITY OF SOLUTION, AND MANNER OF APPLICATION.

The spray solution is prepared by dissolving one and one-half or two pounds of iron sulfate (also called copperas and green vitriol) in each gallon of water. The weaker solution appears to be entirely satisfactory, and is probably the one to be preferred. Used at this strength the quantity of iron sulfate required for a single application is approximately 175 pounds per acre or four pounds per thousand square feet of lawn. A gallon of the solution will cover about 375 square feet. Iron sulfate for spraying purposes is usually offered for sale in the granular or "sugar" form, which is readily soluble in water. It is comparatively inexpensive, costing, usually, from one to two dollars per bag of one hundred pounds. Since it corrodes metals, the solution should be prepared in wooden or earthenware vessels.

Experience has demonstrated rather conclusively that the effectiveness of the spray solution upon the dandelions depends, to a considerable extent, upon the manner in which it is applied. The best results are secured when the solution is applied in the form of a fine, mist-like spray well driven down among the foliage. While fairly satisfactory results may be expected when the solution is applied judiciously with a sprinkling can, it is recommended that some form of a spray pump be used. The kind of outfit selected should depend upon the size of the area to be treated. For small lawns a compressed-air sprayer, knapsack sprayer, or good bucket pump with brass cylinder, and equipped with a fine nozzle will be found satisfactory; while for large lawns a sprayer mounted on wheels is desirable. For very large areas (parks, roadsides, etc.) a power-driven field or orchard sprayer will be found most practical. A lead of hose at least 80 to 100 feet long should be used on the power outfits. In any case, the nozzle should be capable of delivering a fine mist-like spray which will drift evenly over the foliage, and the area should be sprayed evenly, avoiding the drenching of any particular part. One of the new type spray-guns attached to a power sprayer will be found to facilitate the work very materially when it is desired to cover a large area quickly and evenly.

The spray solution should be strained thru a fine strainer or two thicknesses of cheesecloth to remove any particles which would clog the nozzles.

CAUTION.

On stone, cement, metals, and cloth, iron sulfate solution produces a conspicuous yellowish-brown rusty stain which is extremely difficult to remove. Accordingly, care should be taken to avoid getting any of the spray on one's clothing or on sidewalks, building foundations, monuments, curbstones and the like. Even the dragging of the wet hose across stone or cement sidewalks will stain them. In our experiments when working around sidewalks and buildings, we have found it convenient to use a screen made of cloth tacked over a light wooden frame (3 by 6 feet). A helper is required to hold the screen in position and move it from place to place as needed.

After using, the sprayer should be washed out thoroly with clean water to prevent serious rusting. The working parts of the spray pump should be kept well oiled.

AFTER-TREATMENT MEASURES.

Our experiments and experience demonstrate that it is necessary to supplement the spraying operations with at least two after-treatment measures, namely, fertilization and reseeding.

FERTILIZATION.

The fertilization of lawns is essential in order to produce a thrifty growth of grass and dense turf for a protection against the encroachment of weeds. In our experiments, five methods of fertilization, in the form of surface applications, were tested in conjunction with spraying. Briefly, they are as follows:

(1) Spring and fall applications of bonemeal at the rate of 1000 pounds per acre, the fall application giving the best results.

(2) The application of slaked lime at the rate of 1000 pounds per acre. No noticeable response was secured from this treatment.

(3) The application of nitrate of soda at the rate of 100 pounds per acre in the spring after active growth had begun, and again in summer. This gave good results in the form of increased growth of the grass.

(4) The application of a complete commercial fertilizer in the fall.

(5) The use of well-rotted stable manure applied in the fall, and the coarse material raked off the following spring.

The results seem to indicate rather conclusively that the average lawn will require some form of fertilization to quicken grass growth and heal the turf after the dandelions and other weeds have been killed out.[2] When well-rotted stable manure free from weed seeds cannot be obtained, perhaps the best course to follow would be to use a liberal quantity of complete commercial fertilizer in the fall after spraying and apply ground bone during the following two years.

SEEDING.

The renovation of lawns by heavy reseeding with grass seed or grass seed containing a little white clover, to thicken the turf and crowd out the dandelions, has been reported as having given good success in some cases.

Following the use of the spray solution in our experiments, it was found quite necessary to reseed the scars or bare spots in the turf left by the dead weeds. For this purpose a mixture of equal parts of Kentucky blue grass and red top grass seed was used. This was sown on the sprayed lawn, and well raked into the bare spots, after which a dressing of compost was applied. The success attained by this method seems to warrant the following recommendation: Keep at hand, in a dry place, a supply of grass seed mixture containing equal parts of Kentucky blue grass and redtop grass seed known

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[2] The subject of lawn fertilization is fully discussed in U. S. Dept. Agr. Farmers' Bulletin No. 494, which will be sent free from the Department, Washington, D. C.

to be quite free from weed seeds. The two kinds of seed should be purchased separately and mixed at home. The prepared lawn mixtures upon the market are usually of very poor quality. They should never be used unless known by test to be composed of pure fresh seed. The home-mixed seed should be sown on the lawn in the spring (April or May) and again in September following spraying, and well raked into the bare spots left by the weeds. A satisfactory seeding requires five pounds of this mixture for a lot 50 x 100 feet, or one ounce per 100 square feet, at each application. If no spraying is to be done the following season, it is often advisable to add four ounces or more of white clover seed to each five pounds of the mixture. White clover responds quickly and aids in forming a dense growth over bare places where weed seeds may lodge and germinate.

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New York Agricultural Experiment Station.

GENEVA, N. Y.

PART OF
BULLETIN NO. 466.
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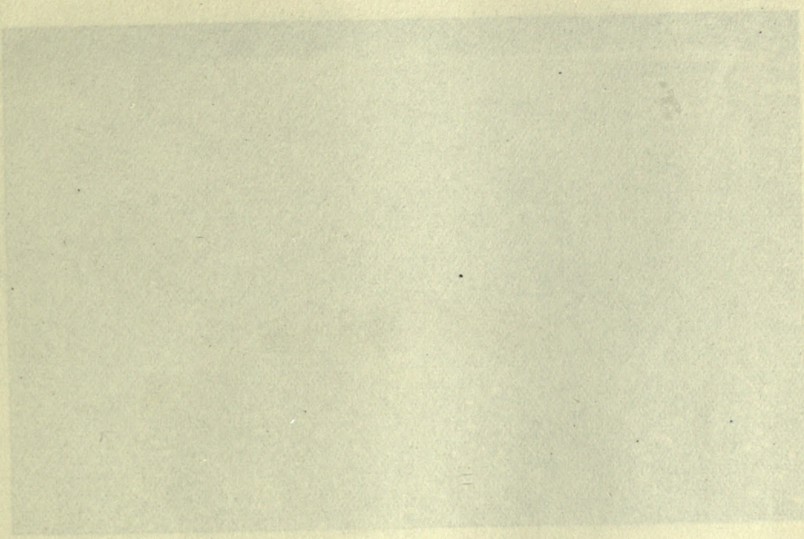
SPRAYING LAWNS WITH IRON SULFATE TO ERADICATE DANDELIONS.

M. T. MUNN.



Dandelion Spraying Experiment.

PUBLISHED BY THE STATION.

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Address all correspondence, not to individual members of the staff, but to the NEW YORK AGRICULTURAL EXPERIMENT STATION, GENEVA, N. Y.

The Bulletins published by the Station will be sent free to any farmer applying for them.

*Connected with Grape Culture Investigations.

[Part* of]

BULLETIN No 466.

SPRAYING LAWNS WITH IRON SULFATE TO ERADICATE DANDELIONS.

M. T. MUNN.

SUMMARY.

Experiments made at the Station during the past eight years demonstrate that dandelions may be eradicated from lawns, at relatively slight expense and without material injury to the grass, by proper spraying with an iron sulfate solution. Ordinarily, four or five applications are required. The first spraying should be made in May just before the first blooming period. One or two others should follow at intervals of three or four weeks; and, finally, one or two more in late summer or fall. During the hot, dry weather of mid-summer spraying should be discontinued because of the danger of injury to the grass. A conspicuous blackening of the lawn which follows each application soon disappears if the grass is growing vigorously. Of the other common lawn weeds, some are killed while others are but slightly injured by the spraying. Unfortunately, white clover, also, is killed. Spraying should be supplemented by the use of fertilizers and the application of grass seed in the spring and fall of each year. With proper management, it is necessary to spray only about every third year in order to keep a lawn practically free from dandelions.

The cutting-out method of fighting dandelions is laborious and ineffective unless the greater part of the root is removed. Shallow cutting, unless done frequently, is worse than none at all, because each cut-off root promptly sends up one or more new plants.

Tests of certain after-treatment measures in the form of reseeding, liming of the soil, and fertilization with commercial fertilizers and stable manure, used in conjunction with the spraying operations, gave results which serve highly to recommend their use either singly or in combination on lawns.

A study of seed production in the common dandelion shows it to be parthenogenetic, that is, capable of producing viable seeds without fertilization of the ovules by pollen.

* The complete bulletin may be had on application to the Station.

CONCLUSIONS AND RECOMMENDATIONS.

OUTLINE OF LAWN TREATMENT.

Eternal vigilance is the price of a good lawn free from weeds. The proper time to commence the fight against weeds is when the lawn is first made. Care should be taken to secure a thick, thrifty growth of grass at the start. Attempts to establish lawns on poor soil illy-prepared usually fail. After the lawn is established constant care is necessary to maintain it in a thrifty condition which will serve as a protection against weeds.

The measures most frequently used for the eradication of weeds from lawns are: (a) digging them out with a knife or spud; (b) heavy reseeding and fertilization to crowd them out; and (c) the use of chemical sprays to kill the foliage. The last-named method is the cheapest and as effective as any; but complete success requires the use of all three methods and some others.

The dandelion and certain other weeds may be eradicated from lawns, without injury to the grass, by proper spraying with iron sulfate solution. However, the weeds will soon return unless supplementary measures are employed. Unfortunately, there is no escape from the menace of dandelions seeding on adjacent grounds, because one has no control over the premises of his neighbors. Nevertheless, the occasional plants which survive spraying should be prevented from seeding by digging them out or by applying gasoline, kerosene, or dry iron sulfate to their crowns. The lawns should be mowed frequently, watered in dry weather, well fertilized, and the bare spots reseeded. Whenever the dandelions reappear in considerable numbers it will be necessary to again resort to spraying.

CUTTING DANDELIONS.

Cutting off dandelions below the crown with a knife or spud is not only laborious but ineffective unless practically the entire root is removed or the foliage completely removed several times during the season, so that the plant has no opportunity to store up reserve food in the root. Shallow digging, unless done frequently, is worse than no digging because the root, when cut off, sends up from one to several new plants and the final result is a more profuse growth of dandelions. Deep digging, whereby practically the entire root is removed with a spud, stiff-bladed knife, asparagus knife, chisel, or other special tool, is recommended as a means of removing the few plants which survive spraying.

SPRAYING LAWNS.

Spraying with iron sulfate solution will usually prove effective when carefully, persistently and intelligently done.

NUMBER OF TREATMENTS AND TIME OF MAKING THEM.

Our experiments indicate that at least three (or, usually, five) thoro applications during a season are necessary to eradicate the dandelions from the average lawn in this state. To be the most effective, the spraying should be repeated as soon as the dandelion plant has regained new foliage and just before it is full grown — usually when the leaves are three or four inches long. This forces the plants to use up their reserve food stored in the roots, and eventually starves them. On the Station lawns, which were exposed to dandelion seeds from adjoining untreated lawns, it was found necessary to spray every second or third year, and to supplement the spraying with other control measures.

The time of application appears to be important. In our tests, the best results were secured when the first application was made in early spring after the central blossom buds were formed, but before blossoming. The first application should be followed by two or three later ones at intervals of three to four weeks during the spring growing season, and one or two others in late summer or fall. The last application should be made late enough in the summer or fall to prevent the plants from recovering before the close of the growing season.

A suitable day for spraying is one on which there is little wind and slight probability of rain for several hours. The sky may be either cloudy or clear. A heavy dew the following night is advantageous. Spraying should be discontinued during periods of drought in midsummer, when the grass is inactive and soil is very dry. Serious injury to the grass may result from spraying at such times. As far as possible, it should be arranged to spray two or three days after mowing and to mow two or three days after spraying.

STRENGTH AND QUANTITY OF SOLUTION, AND MANNER OF APPLICATION.

The spray solution is prepared by dissolving one and one-half or two pounds of iron sulfate (also called copperas and green vitriol) in each gallon of water. The weaker solution appears to be entirely satisfactory, and is probably the one to be preferred. Used at this strength, the quantity of iron sulfate required for a single application is approximately 175 pounds per acre, or four pounds per thousand square feet of lawn. A gallon of the solution will cover about 375 square feet. Iron sulfate for spraying purposes is usually offered for sale in the granular or "sugar" form, which is readily soluble in water. It is comparatively inexpensive, costing, usually, from one to two dollars per bag of one hundred pounds. Since it corrodes metals, the solution should be prepared in wooden or earthenware vessels.

Experience has demonstrated rather conclusively that the effectiveness of the spray solution upon the dandelions depends, to a considerable extent, upon the manner in which it is applied. The best results are secured when the solution is applied in the form of a fine, mist-like spray well driven down among the foliage. While fairly satisfactory results may be expected when the solution is applied judiciously with a sprinkling can, it is recommended that some form of a spray pump be used. The kind of outfit selected should depend upon the size of the area to be treated. For small lawns a compressed-air sprayer, knapsack sprayer, or good bucket pump with brass cylinder, and equipped with a fine nozzle will be found satisfactory; while for large lawns a sprayer mounted on wheels is desirable. For very large areas (parks, roadsides, etc.) a power-driven field or orchard sprayer will be found most practical. A lead of hose at least 80 to 100 feet long should be used on the power outfits. In any case, the nozzle should be capable of delivering a fine mist-like spray which will drift evenly over the foliage, and the area should be sprayed evenly, avoiding the drenching of any particular part. One of the new type spray-guns attached to a power sprayer will be found to facilitate the work very materially when it is desired to cover a large area quickly and evenly.

The spray solution should be strained thru a fine strainer or two thicknesses of cheesecloth to remove any particles which would clog the nozzles.

CAUTION.

On stone, cement, metals, and cloth, iron sulfate solution produces a conspicuous yellowish-brown rusty stain which is extremely difficult to remove. Accordingly, care should be taken to avoid getting any of the spray on one's clothing or on sidewalks, building foundations, monuments, curbstones and the like. Even the dragging of the wet hose across stone or cement sidewalks will stain them. In our experiments, when working around sidewalks and buildings, we have found it convenient to use a screen made of cloth tacked over a light wooden frame (3 by 6 feet). A helper is required to hold the screen in position and move it from place to place as needed.

After using, the sprayer should be washed out thoroly with clean water to prevent serious rusting. The working parts of the spray pump should be kept well oiled.

AFTER-TREATMENT MEASURES.

Our experiments and experience demonstrate that it is necessary to supplement the spraying operations with at least two after-treatment measures, namely, fertilization and reseeding.

FERTILIZATION.

The fertilization of lawns is essential in order to produce a thrifty growth of grass and dense turf for a protection against the encroachment of weeds. In our experiments, five methods of fertilization, in the form of surface applications, were tested in conjunction with spraying. Briefly, they are as follows:

(1) Spring and fall applications of bonemeal at the rate of 1000 pounds per acre, the fall application giving the best results.

(2) The application of slaked lime at the rate of 1000 pounds per acre. No noticeable response was secured from this treatment.

(3) The application of nitrate of soda at the rate of 100 pounds per acre in the spring after active growth had begun, and again in summer. This gave good results in the form of increased growth of the grass.

(4) The application of a complete commercial fertilizer in the fall.

(5) The use of well-rotted stable manure applied in the fall, and the coarse material raked off the following spring.

The results seem to indicate rather conclusively that the average lawn will require some form of fertilization to quicken grass growth and heal the turf after the dandelions and other weeds have been killed out.[2] When well-rotted stable manure free from weed seeds cannot be obtained, perhaps the best course to follow would be to use a liberal quantity of complete commercial fertilizer in the fall after spraying and apply ground bone during the following two years.

SEEDING.

The renovation of lawns by heavy reseeding with grass seed or grass seed containing a little white clover, to thicken the turf and crowd out the dandelions, has been reported as having given good success in some cases.

Following the use of the spray solution in our experiments, it was found quite necessary to reseed the scars or bare spots in the turf left by the dead weeds. For this purpose a mixture of equal parts of Kentucky blue grass and redtop grass seed was used. This was sown on the sprayed lawn, and well raked into the bare spots, after which a dressing of compost was applied. The success attained by this method seems to warrant the following recommendation: Keep at hand, in a dry place, a supply of grass seed mixture containing equal parts of Kentucky blue grass and redtop grass seed known to be quite free from weed seeds. The two kinds of seed should be purchased separately and mixed at home. The prepared lawn mixtures upon the market are usually of very poor quality. They should never be used unless known by test to be composed of pure fresh seed. The home-mixed seed should be sown on the lawn in the spring (April or May) and again in September following spraying, and well raked into the bare spots left by the weeds. A satisfactory seeding requires five pounds of this mixture for a lot 50 x 100 feet, or one ounce per 100 square feet, at each application. If no spraying is to be done the following season, it is often advisable to add four ounces or more of white clover seed to each five pounds of the mixture. White clover responds quickly and aids in forming a dense growth over bare places where weed seeds may lodge and germinate.

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[2] The subject of lawn fertilization is fully discussed in U. S. Dept. Agr. Farmers' Bulletin No. 494, which will be sent free from the Department, Washington, D. C.

OFFICE OF STATE FORESTER

UNDER CONTROL OF

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

W. B. BIZZELL, President

E. O. SIECKE, State Forester

TREE PLANTING

IN

TEXAS TOWNS AND CITIES

BY

LENTHALL WYMAN

Assistant State Forester

BULLETIN 11

OFFICE OF STATE FORESTER

COLLEGE STATION, TEXAS

SHADE TREES IN TEXAS TOWNS AND CITIES

INTRODUCTION

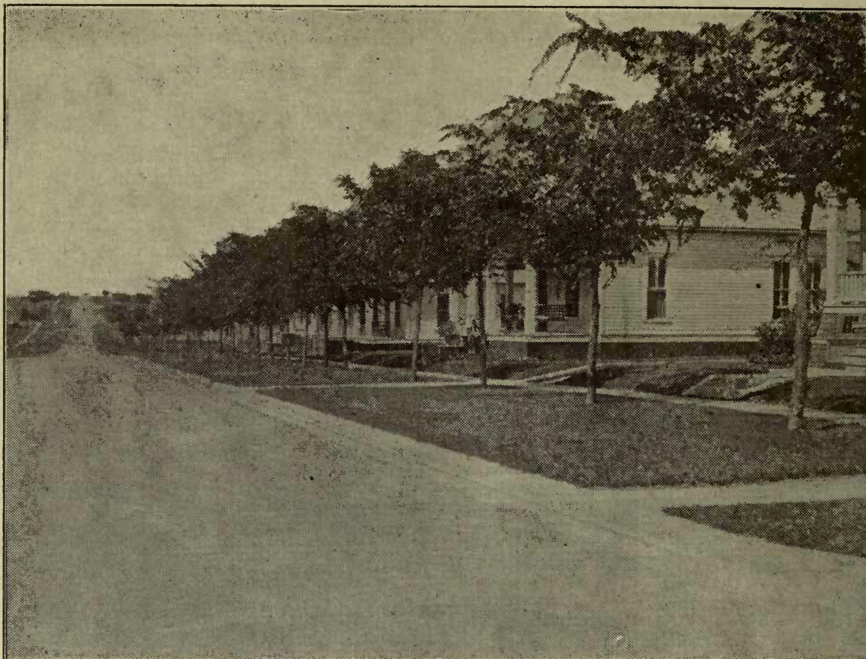
Convenience, comfort, and attractiveness are three qualities which a home seeker requires before he purchases his residence. The same qualities are desired by the community in its home—the city. Many cities are making strenuous efforts to attract new enterprises and to get new citizens. They are improving their conveniences by paving streets, extending street lights, water systems, and sewerage. They are endeavoring to make their municipality more comfortable by watering streets, securing public benefits such as car lines and in many other ways. Most towns and cities are trying to instill a sense of civic pride in their residents through the efforts of Women's Clubs and Chambers of Commerce. The aim is to make the city more beautiful, to attract visitors and influence them to take up residence in the community.

In no other way can the comfort and attractiveness of a town be secured so cheaply, easily, and satisfactorily as by the extensive planting of shade trees and shrubs. This is a form of city improvement which increases in value from the moment it is undertaken and continues to increase in value for many years, whereas sidewalks, electric lights, and drinking fountains begin to deteriorate as soon as they are installed.

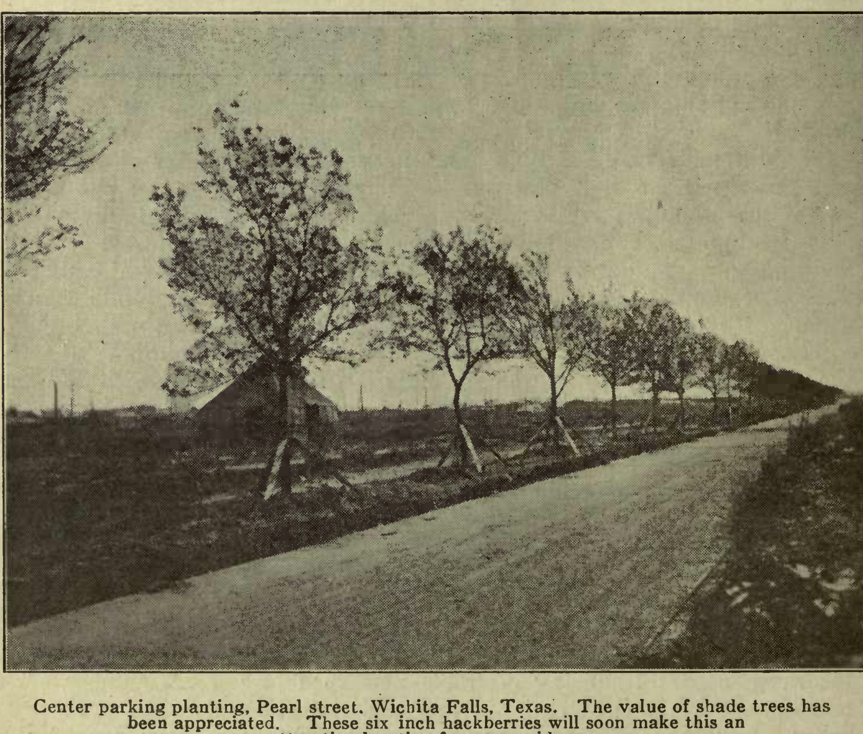
Trees are especially needed in cities to purify the air and to ameliorate the hot summer days. They are a valuable asset to a man's property as is recognized by real estate men when they are boosting a new city addition. The first thing done in such cases is to lay off streets and put attractive sign posts on the corners, next trees are put out and if the promoters are ambitious perhaps an impressive gateway will be built to attract the eyes of prospective buyers. The street signs and gateway are advertisement, but the trees represent real value. They are planted because in no other way could the real estate man enhance the value of the property so much with so small an outlay.

There is great need for more trees in every Texas community and in the hope that a planting movement will get under way with fresh impetus this bulletin is issued to serve as a guide for city planters. During the past fifteen to twenty years a great many species of trees have been planted in West Texas and the Panhandle. Although many of these were failures still many others proved to be suited to the soil and climate of the region. In order to get the benefit of the results of these plantings a six weeks' trip was made through the northwestern part of the State. The information obtained on the trip has been largely used in the preparation of this bulletin.

The Division of Forestry of the Texas Experiment Station is conducting tests on eleven sub-stations in various sections of the State for the purpose of introducing desirable new shade trees. A number of new species are being tried out and demonstrative planting work is being conducted. Although the experiments have been in progress for



Excellent tree planting on the side parking of a street in Temple, Texas. The ground around the roots has been spaded up.



Center parking planting, Pearl street, Wichita Falls, Texas. The value of shade trees has been appreciated. These six inch hackberries will soon make this an attractive location for new residences.

only four years yet several new species show promise of being adapted for planting work in the plains region. From time to time new trees are sure to be added to the list of those recommended in this bulletin as a result of the Experiment Station work as soon as the tests have been carried on for a long enough period to show conclusively which trees are best suited to each locality.

SELECTION OF TREES

Once the property owner has decided to set out trees the question arises: what species should he use? Trees which do well in the Panhandle will not prove desirable below the cap rock. Trees suitable for planting in wide parkings are poor varieties for narrow streets. In general, long lived trees should be selected. Trees should be chosen which do not sprout up from the roots or have disagreeable odors. Many otherwise admirable trees are untidy because of the quantities of fruit which fall and attract flies. Others lose their leaves early and should be avoided. The natural form should be such as not to necessitate constant pruning. Trees for narrow streets should have narrow columnar crowns, such as Lombardy poplar, while wide avenues are adapted to broad spreading species like the American elm and live oak. Cedar trees should not be planted close to apple trees or hawthorns because of the rust which has alternate stages on each of these trees. Black locust is undesirable in regions like Amarillo where the locust borer has become established. It is impossible in a short bulletin to go fully into the qualifications of each tree which might be used in Texas. The following table will briefly show trees adapted or suited to varying conditions:

TREES ADAPTED TO NARROW STREETS

Lombardy poplar	Black locust	Mesquite
Silver maple	Hackberry	Silver poplar
Tree of heaven	Carolina poplar	
Gingko	Box elder	

TREES ADAPTED TO WIDE AVENUES

Oaks	Honey locust	Willow
Elm	Magnolia	Walnut
Sycamore	Pecan	Camphor tree
Sweet gum	Ash	Mulberry
Basswood	Cottonwood	Russian olive
Tulip tree	Eucalyptus	Bois d'arc

TREES FOR VERY SEVERE CITY CONDITIONS—NARROW PARKINGS, OIL, SMOKE, ETC.

Tree of heaven	Sycamore
European plane tree	Gingko

SHORT-LIVED TREES

Poplar	Silver maple	Hackberry
Chinaberry	Box elder	Black locust

UNTIDY TREES

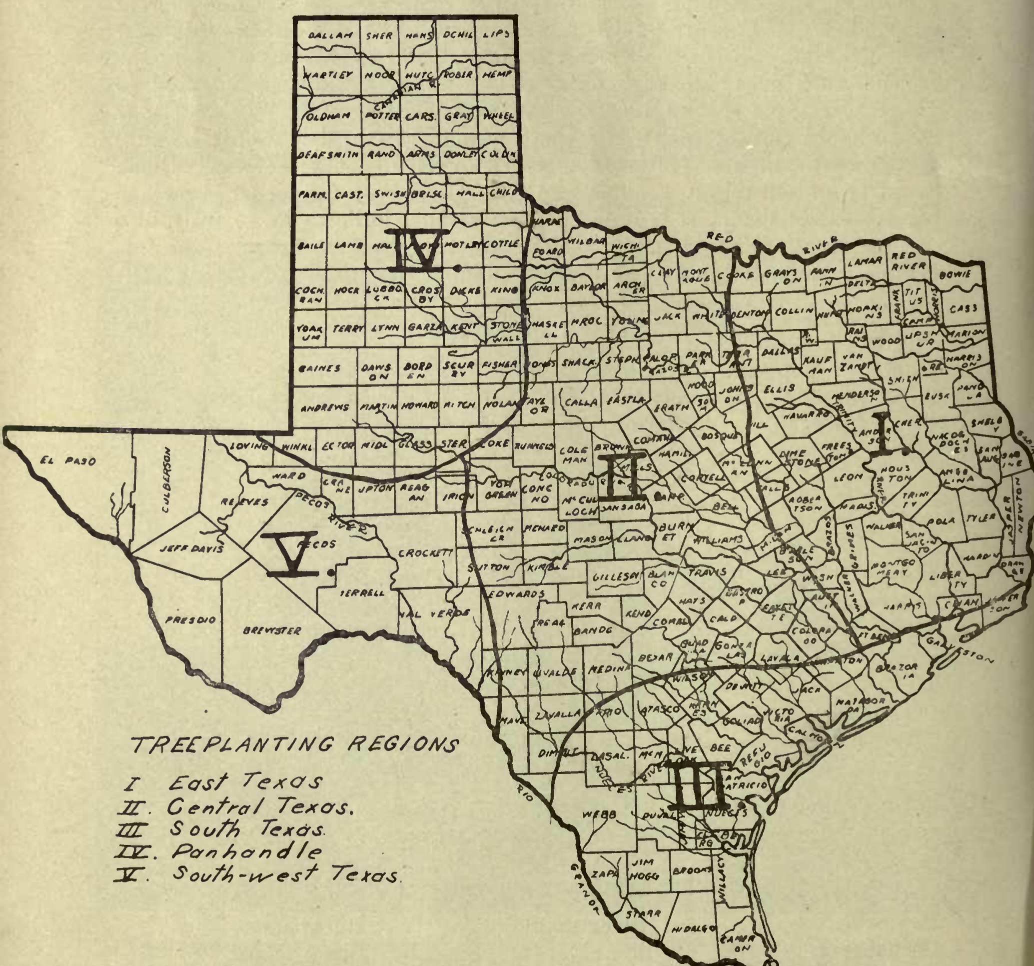
Eucalyptus	Cottonwood	Bois d'arc, female
Mulberry	Willow	Japanese varnish
Black locust	Gingko	
Chinaberry	Tree of heaven, female	

TREES SPROUTING BADLY FROM THE ROOTS

Tree of heaven	Cottonwood	Black locust
Poplar	Willow	

UNDESIRABLE STREET TREES IN REGIONS WHERE OTHER VARIETIES THRIVE

Cottonwood	Tree of heaven	Box elder
Carolina poplar	Chinaberry	Evergreens
Willow	Silver maple	



COMMON SHADE TREES AND THEIR CHARACTERISTICS.

Common name	Scientific name	Rate of growth	Length of life	Value for street planting	Width of street to which adapted	Undesirable features	Region where tree does well*
Box elder	Acer negundo	Fast	Medium	Fair	Narrow	Brittle, liable to insect attack	II, III, IV, V
Silver maple	Acer saccharinum	Fast	Short	Fair	Narrow	Brittle	II, III, IV, V
Sugar maple	Acer saccharum	Slow	Long	Fair	Wide	Won't thrive in city streets	I
Paradise tree	Ailanthus glandulosa	Fast	Medium	Fair	Narrow	Root suckers, straggly, odor	I, II
Paper mulberry	Broussonetia papyrifera	Medium	Short	Poor	Narrow	Freezes back, hurt by wind	I, II, IV, V
Catalpa	Catalpa speciosa	Medium	Medium	Fair	Narrow	Becomes irregular in shape	I, II, IV, V
Hackberry	Celtis occidentalis	Fast	Medium	Fair	Medium	Badly attacked by insects, short-lived	I, II, III, IV
Sugarberry	Celtis mississippiensis	Fast	Medium	Fair	Medium	Badly attacked by insects, short-lived	I, II, III, IV
Flowering willow	Chilopsis linearis	Slow	Short	Poor	Narrow	Small tree	I, II, IV, V
Orange	Citrus sp	Medium	Medium	Fair	Narrow	Fruit	III
Russian olive	Elaeagnus angustifolia	Fast	Medium	Fair	Medium	Low branching system	II, IV, V
Blue gum	Eucalyptus globulus	Fast	Long	Poor	Medium	Dirty, sheds leaves and fruit	III
Green ash	Fraxinus lanceolata	Medium	Medium	Excellent	Medium	Fruit objectionable	II, IV, V
White ash	Fraxinus americana	Medium	Long	Excellent	Medium	Fruit objectionable	I
Gingko	Gingko biloba	Slow	Medium	Good	Medium	Fleshy fruit	I, II

*See Map page 6

SHADE TREES AND THEIR CHARACTERISTICS.

Common name	Scientific name	Rate of growth	Length of life	Value for street planting	Width of street to which adapted	Undesirable features	Good points, remarks	Region where tree does well*
Honey locust......	Gleditsia triacanthos......	Medium...	Medium...	Fair......	Medium...	Thorns, need pruning.	Light foliage for narrow streets.	I, II, IV, V
Pecan............	Hicoria pecan...........	Medium...	Long......	Excellent..	Wide.....	Needs moisture, nuts.	Fine tree for East and Central Texas.	I, II, III
Walnut..........	Juglans nigra...........	Slow......	Long......	Good.....	Wide.....	Nuts...............	Valuable timber......	I, II, III, IV
Varnish tree.......	Koelreuteria paniculata...	Medium...	Medium...	Fair......	Medium...	Not sufficiently tested	Stands drought and alkali.	I, II, IV
Sweet gum........	Liquidambar styraciflua...	Medium...	Long......	Excellent..	Wide.....	Fruit...............	Hardy tree..........	I
Tulip tree.........	Liriodendron tulipifera....	Medium...	Long......	Excellent..	Wide.....	Fruit...............	Introduced to East Texas.	I
Chinaberry........	Melia azedarach..........	Fast......	Short.....	Poor......	Narrow...	Fruit, brittle wood, irregular.	Useful only for quick shade.	I, II, III, V
Umbrella China....	Melia azedarach umbraculifera.	Fast......	Short.....	Poor......	Narrow...	Fruit, brittle wood, irregular.	Very dense shade.....	I, II, III, V
Red mulberry	Morus rubra.............	Medium...	Medium...	Poor......	Medium...	Fruit attracts flies....	Fair tree in chicken yards.	I, II, III, IV, V
White mulberry....	Morus alba..............	Medium...	Medium...	Poor......	Medium...	Fruit attracts flies....	Fair tree in chicken yards	I, II, III, IV,V
Russian mulberry..	Morus alba tartarica......	Medium...	Medium...	Poor......	Narrow...	Bushy..............	Stands drought.......	I, II, IV, V
Oleander..........	Nerium oleander.........	Medium...	Medium...	Good.....	Home grounds.	Not large...........	Showy flowers........	III
Black gum.........	Nyssa sylvatica..........	Medium...	Medium...	Good.....	Narrow...	Fruits..............	Beautiful fall foliage..	I, III
Huisache..........	Acacia farnesiana.........	Slow......	Medium...	Poor......	Home grounds.	Bushy..............	Too small, fragrant flowers.	II, III, V
Sycamore..........	Plantanus occidentalis....	Fast......	Long.....	Excellent.	Wide.....	Has leaf blight.......	Stands severe conditions.	I, II, III. IV
European plane....	Platanus orientalis........	Fast......	Long......	Excellent..	Wide.....	....	More compact than sycamore.	I, II, III, IV

*See Map page 6

SHADE TREES AND THEIR CHARCTERISTICS.

Common name	Scientific name	Rate of growth	Length of life	Value for street planting	Width of of street to which adapted	Undesirable features	Good points, remarks	Region where tree does well*
Black locust	Robinia pseudacacia	Fast	Medium	Fair	Medium	Suckers, attacked by insects.	Stands drought and alkali.	II, IV, V
Willow	Salix nigra	Fast	Medium	Poor	Wide	Sprouts, brittle	All right around tanks	I, II, III, IV, V
Tallow tree	Sapium sebiferum	Medium	Medium	Fair	Narrow	Small		I, II
Pagoda tree	Sophora japonica	Medium	Medium	Fair	Medium	Not tried out sufficiently.		I, II, III
Japanese varnish tree.	Sterculia platanifolia	Medium	Medium	Good	Medium	Not tried out sufficiently.	Smooth green bark	I, II, III
Salt cedar	Tamarix spp	Fast	Short	Poor	Lawns only	Gets straggly	Stands drought, good hedge tree.	II, III, IV, V
Cypress	Taxodium distichum	Medium	Long	Fair	Medium	Dirty	Needs moisture	I, III
Basswood	Tilia americana	Medium	Medium	Good	Medium	Good bee tree	Needs moisture	I, III
Bois d' arc	Toxylon pomiferum	Medium	Long	Good	Wide	Fruit bad, needs pruning.	Very hardy, good form	I, II, IV, V
American elm	Ulmus americana	Medium	Long	Excellent	Wide	Hurt by insects	Fine form, stands drought.	I, II, IV
Cedar elm	Ulmus crassifolia	Slow	Short	Poor	Narrow	Loses leaves early	Stands drought	II, IV
Slippery elm	Ulmus fulva	Medium	Medium	Fair	Medium	Not best shape for shade tree.	Needs moisture	I, II
Silver poplar	Populus alba	Fast	Short	Fair	Narrow	Dirty, brittle	Ornamental, good around tanks and ditches.	II, III, IV, V
Carolina poplar	Populus eugenia	Fast	Short	Poor	Narrow	Short-lived, temporary	Fine for quick effect, good for tanks.	I, II, III, IV, V
Lombardy poplar	Populus nigra italica	Fast	Short	Fair	Narrow	Short-lived, needs water.	Fine for quick effect, good for tanks.	I, II, III, IV, V
Cottonwood	Populus deltoides	Fast	Short	Poor	Medium	Poor shape, brittle		II, III, IV, V

*See Map page 6

SHADE TREES AND THEIR CHARACTERISTICS.

Common name	Scientific name	Rate of growth	Length of life	Value for street planting	Width of street to which adapted	Undesirable features	Good points, remarks	Region where tree does well*
Empress tree	Paulonia imperialis	Medium	Short	Poor	Narrow	Small	Large leaves, tropical effect, purple flowers	I, II, IV
Mesquite	Prosopis juliflora	Slow	Medium	Poor	Narrow	Straggly pods	Very hardy	II, III, IV,V
Pomegranate	Punica granatum	Slow	Medium	Poor	Narrow	Bushy		I, II, III
White oak	Quercus alba	Medium	Long	Good	Wide		Free from insects, need moisture.	I, II, III
Post oak	Quercus minor	Medium	Long	Fair	Wide		Stands dry situation	I, II, III
Water oak	Quercus nigra	Medium	Medium	Fair	Wide		Needs moist place	I, II, III
Willow oak	Quercus phellos	Medium	Medium	Excellent	Wide		Needs moist place	I, II, III
Overcup oak	Quercus lyrata	Medium	Long	Good	Wide		Needs moist place	I, II, III
Burr oak	Quercus macrocarpa	Medium	Long	Excellent	Wide		Needs moist place	I, II, III
Texan oak	Quercus texana	Medium	Medium	Good	Medium		Does well in cities and dry places	I, II, III
Spanish oak	Quercus digitata	Medium	Medium	Good	Medium		Best of red oaks	I, II, III
Black Jack oak	Quercus marylandica	Slow	Short	Poor	Not suited	Straggly	Stands dry poor soil	I, II, III
Blue Jack oak	Quercus cinerea	Slow	Short	Poor	Not suited		On sand hills	I
Black oak	Quercus velutina	Medium	Long	Good	Wide		Needs moisture	I
Yellow oak	Quercus muhlenbergii	Medium	Long	Good	Wide		Needs moisture	I, II, III
Cow oak	Quercus michauxii	Medium	Long	Good	Wide		Needs moisture	I, II. III

*See Map page 6

EVERGREEN SHADE TREES AND THEIR CHARACTERISTICS.

Common name	Specific name	Rate of growth	Age	Value for lawn planting	Undesirable features	Good points, remarks	Region where tree does well*
Himalayan cedar	Cedrus deodora	Fast	Long	Excellent	None	Pyramidal, silvery-feathery	I, II, IV
Camphor tree	Cinnamomum camphora	Medium	Medium	Good	Will not stand wet soil		III
Italian cypress	Cupressus sempervirens	Fast	Medium	Excellent		Stands drought, pyramidal, attractive cones.	I, II, IV, V
Arizona cypress	Cupressus arizonica	Fast	Medium	Excellent		Attractive cones, silver foliage	I. II, III, IV
Red cedar	Juniperus virginiana	Slow	Long	Fair	Spreads cedar apple fungus.		I. II, III, IV
Holly	Ilex opaca	Slow	Medium	Good		Showy berries and foliage	I, III
Magnolia	Magnolia grandiflora	Slow	Long	Excellent	Some litter	Large leaves	I, II, III
Blue spruce	Picea parryana	Slow	Long	Fair		Silver foliage, needs cool moist place	IV, V
Shortleaf pine	Pinus echinata	Fast	Long	Good	Pine shoot moth hurts it.		I, II
Austrian pine	Pinus austriaca	Medium	Long	Fair	Needs care	Stands drought	I, II, IV
Jack pine	Pinus divaricata	Medium	Medium	Fair	Needs care	Rapid grower at first	II, IV, V
Western yellow pine	Pinus ponderosa	Slow	Long	Fair	Needs care		IV, V
Scotch pine	Pinus sylvestris	Fast	Long	Good	Needs care		I, II, IV, V
Loblolly pine	Pinus taeda	Fast	Long	Good	Needs care		I, II, III
Longleaf pine	Pinus palustris	Slow	Long	Good	Needs care		I, III
Live oak	Quercus virginiana	Slow	Long	Excellent		Suited to wide avenues	I, II, III
Chinese arborvitae	Thuja orientalis	Medium	Medium	Good	Gets straggly		I, II, III, IV, V
Arborvitae	Thuja occidentalis	Medium	Medium	Fair	Gets straggly		I, II, III, IV, V
Rosedale arborvitae	Thuja sp	Medium	Medium	Good	Bushy		I, II, III
Olive	Olea europea	Medium	Medium	Fair			III

*See Map page 6

DESCRIPTION OF TREES

MAPLES—There are six maples which grow naturally in Texas, only two of them being desirable shade trees, however. These are the silver maple and the sugar maple. Another species, the ash-leaved maple, or box elder, has been successfully introduced in some parts of the state.

SUGAR MAPLE (*Acer saccharum*)—This is a hardy tree with a compact oval crown; native in East Texas. It is an excellent tree in good soil with plenty of moisture, but will not do well under city conditions. In suburban situations and on lawns it has a distinct value.

SILVER MAPLE OR SOFT MAPLE (*Acer saccharinum*)—A fast growing tree with leaves dark green above and silvery beneath. The tree is rather short-lived with brittle branches. It is difficult to keep silver maple trained properly, and, furthermore, it is often injured by scales and borers.

BOX ELDER (*Acer negundo*)—A tree similar in most characteristics to silver maple. The leaves are not silvery on the under side. The same advantages and drawbacks which apply to silver maple are also applicable to box elder.

TREE OF HEAVEN OR PARADISE TREE (*Ailanthus glandulosa*)—An Asiatic tree introduced to this country many years ago. It is a very rapid grower in its youth but soon becomes straggly and unkempt. The leaves are compound and frond-like. Male and female flowers are borne on separate trees. While the seeds of the female plants are a nuisance they are less objectionable than the disagreeable odor of the staminate flowers. Its habit of sending up root suckers makes the tree of heaven rather undesirable, but under severe city conditions where smoke, dust and insufficient root space make it impossible to plant other trees the tree of heaven will survive and do fairly well.

HARDY CATALPA (*Catalpa speciosa*)—There are two catalpas native in the central states. However, common catalpa is a very unsatisfactory shade tree. It may be distinguished from hardy catalpa by the narrow pointed tuft of hair on the ends of the seeds, whereas hardy catalpa has a broad tuft. Catalpa is moderately fast growing and short-lived, quickly developing an uneven crown with bare branches crowned by bunches of large heart-shaped leaves.

PAPER MULBERRY (*Broussonnetia papyrifera*)—A small Asiatic tree with cordate or three to five lobed leaves, hairy beneath. This tree is rather short-lived and inclined to be bushy, having a round head. It is liable to frost injury but is able to stand severe drouth and soil alkalinity.

HACKBERRY (*Celtis occidentalis*)—The hackberry is a medium sized drouth-resistant tree with an oblong open crown. In Eastern Texas it is severely attacked by borers and leaf gall insects. The hackberry is short-lived except under favorable soil and moisture conditions, and accordingly other trees should be given preference in general. It reaches its best development as a street tree in Central Texas.

SUGARBERRY (*Celtis mississippiensis*)—A tree with habits similar to hackberry. The leaves are large and smoother and the tree reaches a larger size and greater age than the hackberry. Useful in Central and Southwestern Texas.

DESERT WILLOW (*Chilopsis linearis*)—A native of the West Texas draws. It stands drouths and much alkali. It is a small tree with showy flowers and long cylindrical seed pods. The leaves are linear. It is not regular in form, being similar to mesquite and willow in this regard. A desirable tree under severely dry conditions.

ORANGE (*Citrus sp.*)—Various citrus fruit trees are used to advantage as shade trees along the coast below Corpus Christi. Above Corpus Christi citrus trees are often seen but they do not reach the same development that they attain further south and are frequently injured by frost. They are medium sized to small trees with even rounded crown and dark green glossy leaves, being more useful for lawns than for street planting. They will not stand much frost.

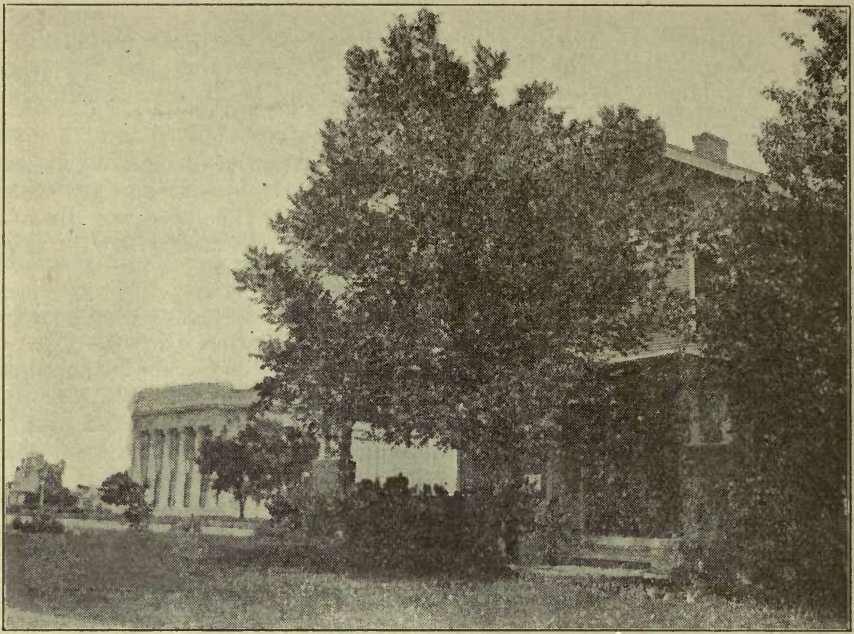
RUSSIAN OLIVE (*Elaeagnus angustifolia*)—A handsome silvery-leaved medium sized tree. It has a broad rounded head with a rather irregular branching system similar to willow or mesquite. It stands drouth and alkali, showing remarkably fast growth. It needs some pruning to make a good shade tree for street purposes.

BLUE GUM (*Eucalyptus globulus*)—Useful for planting along the gulf coast. Freezes back at Port Arthur. A tree reaching great size and age, of very rapid growth, causing roots to ruin walks, sewerage systems and street pavements. Should be planted on wide avenues where it can have some protection, as it will not endure a temperature below 24 degrees Fahrenheit when young. It needs a humid climate with good soil for proper development. With shallow soil or insufficient soil moisture the growth of all eucalyptus trees is seriously retarded. Other varieties may prove successful in Texas but have not been tried out extensively as yet. RED GUM (*E. rostrata*) will stand a temperature of 13 degrees after it becomes established and shows some promise for the Southern coastal region.

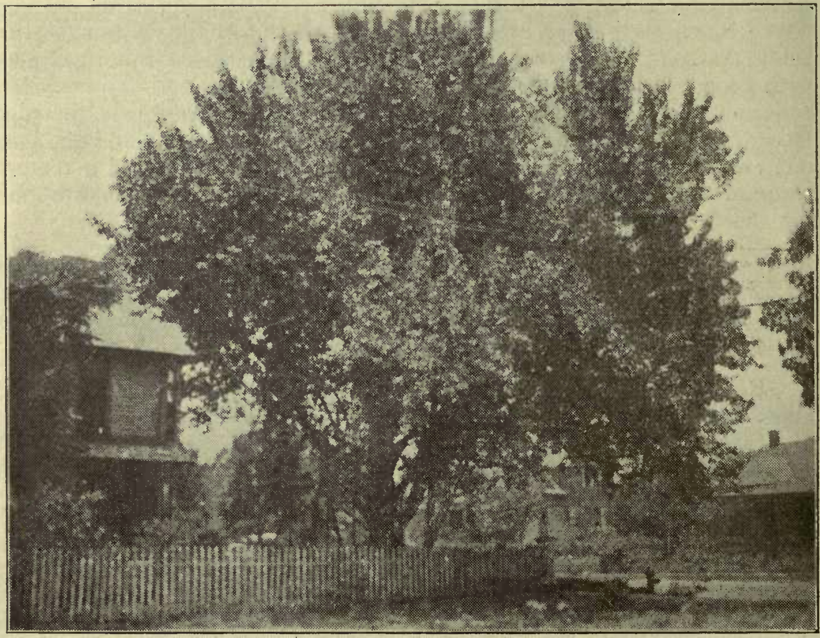
WHITE ASH (*Fraxinus americana*)—This ash is native in East Texas, growing in moist rich soils. The white ash is a large, well-formed tree, fairly clean except for the seeds and a good shade tree, more at home on lawns than on city streets, however.

GREEN ASH (*Fraxinus lanceolata*)—This is one of the best shade trees which will grow in West Texas and the Panhandle. It is somewhat smaller and shorter lived than white ash and stands a dry climate with alkali very well. It is fairly clean, does not break up and makes a shapely tree.

MAIDENHAIR TREE OR GINGKO (*Gingko biloba*)—This is a Chinese tree introduced into the United States a number of years ago. Although it has not been planted extensively in Texas it has shown promise in the northeastern and central black land districts. It cannot be recommended strongly as yet because sufficient data on its adaptability is lacking.



The pecan is the State tree. This one is a vigorous young specimen on the A. & M. College grounds. Except in Southwest Texas and the Panhandle the pecan is one of our best shade trees.



The bois d'arc forms an excellant broad spreading crown. This tree in Denton, Texas, is growing in the region of its best development.

HONEY LOCUST (*Gleditsia triacanthos*)—A tree with light feathery foliage bearing long seed pods which are somewhat of a nuisance. It has a rounded head with stout branches and a strong root system. The thorns are objectionable, but a thornless variety (*G. inermis*) is offered for sale by most nursery dealers. It is a desirable tree for dry regions.

PECAN (*Hicoria pecan*)—The pecan has been designated the official state tree and as such it deserves a special mention. An excellent shade tree and a valuable nut tree, this species is an unusually desirable one to plant in the region of its best development. In the western part of the state it will thrive if given some cultivation and water.

The pecan is rather hard to transplant and its growth is not rapid but it produces a uniform oval crown, is fairly resistant to insects and disease, and is an abundant producer of excellent nuts. This last feature is objectionable where trees are along highways because of the breakage which results when nuts are clubbed off, a situation which frequently arises.

HICKORY (*Hicoria spp.*)—There are several varieties of hickory which grow in East Texas, bitternut, shagbark, pignut, nutmeg and others. All of these would make fair shade trees were it not for their exceptionally slow growth. They require good moist soil and cannot compete with elm, ash, sweet gum and many other faster growing trees.

BLACK WALNUT (*Juglans nigra*)—The walnut is an excellent shade tree. It has a dense crown, is hardy, grows fairly fast, produces excellent nuts and the most valuable wood of any tree grown in Texas. It needs considerable cultivation and should be planted where it will receive a good supply of moisture.

VARNISH TREE, PRIDE OF INDIA (*Koelreuteria paniculata*)—This tree is an exotic from Asia. It appears to stand alkali and low precipitation. It is grown in Kansas and Missouri and should do well in Western Texas. The varnish tree is rather short-lived and does not reach a great size but should be well suited to narrow streets.

SWEET GUM, RED GUM (*Liquidamber styraciflua*)—The sweet gum is one of the best trees for shade in East Texas. It has a symmetrical oval crown, star shaped leaves, and bears small spiny balls of seeds which are attractive in winter. It is a rather fast grower, long-lived and reaches a large size. It should be used in suburban situations since it is not adapted to severe city conditions.

TULIP TREE, YELLOW POPLAR (*Liriodendron tulipifera*)—The largest broad-leafed tree of the Atlantic coast. Although not native to Texas it makes an admirable shade tree where the soil is rich with good drainage. It has a round head with persistent cone-like fruits. It is hard to transplant and needs plenty of room.

CHINABERRY (*Melia azedarach*)—The chinaberry is an Asiatic tree which is much used for a shade tree throughout the state. It is a densely foliaged tree, with brittle wood, and irregular open crown and an abundance of white waxy fruits which make it an untidy tree for planting near sidewalks. It grows remarkably fast but quickly deteriorates, being especially susceptible to wind breakage and subsequent rot. It is a tree which should be used only where quick results are desired and then more permanent trees should be used also, to succeed it after a few years.

UMBRELLA CHINABERRY, TEXAS UMBRELLA (*Melia azedarach umbraçulifera*)—This is an horticultural variety of the preceding species. It develops a flat umbrella-like crown, very dense and regular. It is a very handsome tree and a useful one for formal effects. However, it has most of the defects that the chinaberry has; brittle branches, much litter, and short period of attractiveness.

WHITE MULBERRY (*Morus alba*)—Introduced from Europe. It does well on dry lands but prefers a moist soil. It is a small tree with a round head, fairly well adapted for street planting, but the berries are objectionable on sidewalks. This is the silk-worm tree of Europe.

RED MULBERRY (*Morus rubra*)—A native tree somewhat larger than the above named species. The red mulberry is hardy and makes a good shade tree in dry regions. The fruit attracts flies and is a disagreeable feature.

RUSSIAN MULBERRY (*Morus alba tartarica*)—This tree, a native of Asia, is hardier than any of the other mulberries, and although it is a small bushy tree, still it has some advantages for the treeless portion of the state. At elevations, above 1800 feet it is apt to be killed back by late frost. It is not long-lived but is a fairly rapid grower and not a heavy bearer, which is an advantage for shade purposes.

OLEANDER (*Nerium oleander*)—A large shrub or small tree with a wealth of flowers. It thrives along the coast where the winters are not too severe and does well under severe city conditions.

SOUR GUM, TUPELO (*Nyssa sylvatica*)—A tall tree with slender drooping branches. The foliage is dark green and lustrous, assuming attractive shades in the fall. It is a slow growing tree suited to wet situations. The fleshy fruits are a disadvantage. The COTTON GUM (*Nyssa aquatica*) is very similar to the sour gum.

HUISACHE (*Acacia farnesiana*)—A small thorny tree with fragrant yellow flowers. It makes a fair street tree in Southwestern Texas but is a slow grower and has a somewhat irregular crown.

SYCAMORE (*Platanus occidentalis*)—One of the largest and best shade trees over most of the State. It is a fast grower, develops a large round head of stout branches, and although susceptible to leaf diseases, yet these may be easily controlled by spraying. It is not attacked by insects nor affected by adverse city conditions. Furthermore, although best adapted to wet situations it will thrive with very little moisture and care.

ORIENTAL PLANE TREE (*Platanus orientalis*)—A European tree more enduring of city conditions, and possessing a more compact crown than sycamore, but otherwise similar to it. It is a better tree than sycamore for city purposes, not being affected by leaf blight.

COTTONWOOD (*Populus deltoides*)—A large native tree with trembling leaves, found around water courses. It has a shallow extensive root system, suckers badly, and produces considerable "cotton," all of which is objectionable in a street tree. It is not a desirable tree for city streets and should be used only in exceptional cases and where plenty of water is available.

CAROLINA POPLAR (*Populus eugenia*)—A more desirable tree than the preceding species since it grows faster and has a more regular crown. Useful for quick effects on narrow streets.

LOMBARDY POPLAR (*Populus nigra var. italica*)—A tall, slender, rapid growing poplar used for formal planting on very narrow streets. It is short lived, shallow rooted, liable to send root suckers and objectionable because of the "cotton."

EMPRESS TREE, PRIDE OF INDIA (*Paulonia imperalis*)—A small, fast growing, Asiatic species with purple flowers. It has large leaves of a tropical appearance and is poorly adapted to planting along streets.

MESQUITE (*Prosopis juliflora*)—The mesquite is a fairly good shade tree in the southwestern part of the state. It is a rather slow growing tree with an irregular crown of light foliage. Its only advantage is that it is very hardy and needs very little care.

POMEGRANATE (*Punica granatum*)—A small bushy tree suited to the lower coastal region but not especially adapted to street planting.

OAKS—The oaks, as a class, are excellent street trees. They are with a few exceptions strong, well formed, long-lived and not subject to insect attacks.

WHITE OAK (*Quercus alba*)—A rather slow growing, long-lived, round-headed tree, sturdy, resistant, and cleanly. It makes an ideal street tree where there is plenty of water.

BLUE JACK OAK (*Quercus cinerea*) and BLACK JACK OAK (*Q. marylandica*)—Slow growing, short-lived trees of the sand hills, poorly suited for street purposes or lawn planting.

SPANISH OAK (*Quercus digitata*)—A tree of good form, long-lived, suited to medium or wide streets. It needs considerable moisture.

TEXAS OAK (*Quercus texana*)—Is similar to the Spanish oak.

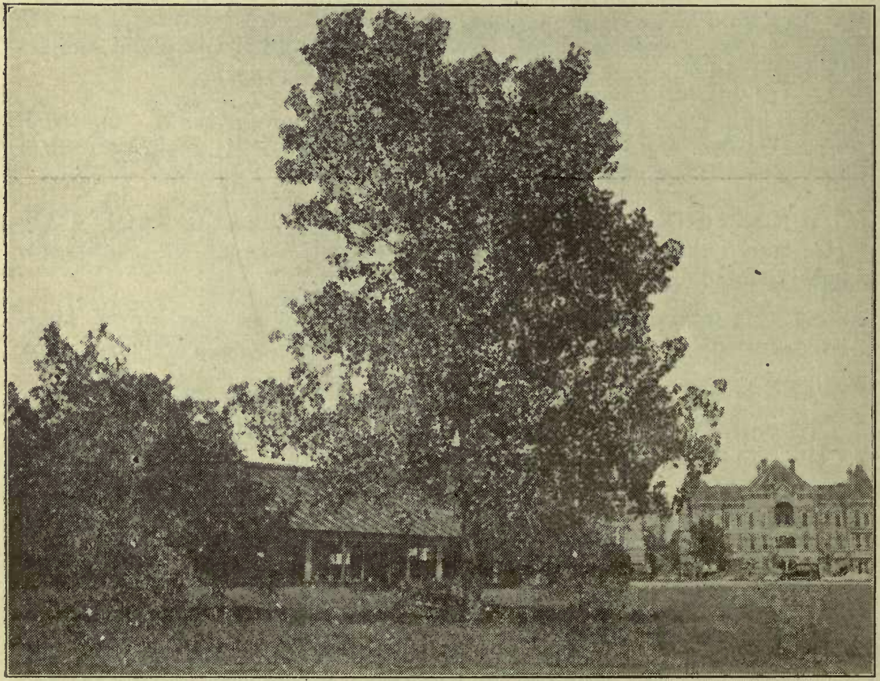
OVERCUP OAK (*Quercus lyrata*), BURR OAK (*Q. macrocarpa*), COW OAK (*Quercus michauxii*), BLACK OAK (*Quercus velutina*), and YELLOW OAK (*Q. muhlenbergii*) are all desirable shade trees.

RED OAK (*Q. rubra*) SCARLET OAK (*Q. coccinea*) are also excellent trees for Northeast Texas.

WATER OAK (*Q. nigra*) and WILLOW OAK (*Q. phellos*) are fast growing excellent shade trees, but cannot do much on dry sandy land.

POST OAK (*Quercus minor*)—This is a very slow growing but long-lived species. Much prized on lawns where it occurs naturally, but

Desirable introduction from the Orient. Japanese varnish trees on the Texas A. & M. College campus. The large leaves, light green, smooth bark and high heads make these good trees for streets or lawns.



Poplars and cottonwoods are fast growing trees but are short-lived. This picture was taken on the Texas A. & M. College campus where the compact soil makes it difficult to grow large well-formed trees.

seldom planted because of the difficulties encountered in transplanting and raising young trees.

BLACK LOCUST (*Robinia pseudacacia*)—A rapid growing, short-lived, light foliaged tree standing considerable drought and alkali. It makes a handsome shade tree and is much used in the Panhandle and West Texas. It has a number of drawbacks, however, since it suckers badly and creates considerable litter with the seed pods. Furthermore, in places it is being exterminated by the locust borer (*Cyllene robinae*). Where the borers are not present it is a valuable lawn and street tree.

BLACK WILLOW (*Salix nigra*)—A fast growing tree useful near water. It is not long-lived, and is too susceptible to disease and insect attacks to make it a good shade tree. Moreover, it is untidy in appearance and the shallow roots are a nuisance, breaking up walks, killing out grass, and when planted too close to ditches the roots tend to fill them up.

CHINESE TALLOW TREE (*Sapium sebiferum*)—The tallow tree is an Asiatic species which does well in Texas. It makes a medium rate of growth but does not reach any great size. It has leaves similar to cottonwood, making a rather attractive small tree for narrow streets.

PAGODA TREE (*Sophora japonica*)—An Asiatic tree of medium size which makes a moderately fast growth and stands a dry climate. The pagoda tree is a good tree for narrow streets in West Texas.

JAPANESE VARNISH TREE (*Sterculia platanifolia*)—The Japanese varnish tree is another Asiatic tree which has found favor in this country. It is a moderately fast growing tree with smooth, light green bark and large leaves, resembling those of the sycamore. It does not form a full crown, but the dense clusters of large leaves on the ends of the branches make a satisfactory shade. This appears to be a desirable shade tree.

BALD CYPRESS (*Taxodium distichum*)—The cypress is a tree best suited to swamps but occasionally excellent specimens are found along road sides and in towns. The cypress is best used where formal effects are desired. It is a rather slow growing tree but a long-lived one, not affected by insects to any extent.

SALT CEDAR, TAMARISK (*Tamarix spp*)—There are several varieties of salt cedar all introduced from foreign countries. They are remarkably hardy and make a good growth. Most varieties are shrubs but with training some may assume tree form. They have light feathery foliage similar to the cedars but the leaves are shed in the winter time. Only valuable for street purposes where other trees do not grow, particularly in the Trans-Pecos region.

BASSWOOD, LINDEN (*Tilia americana*)—The linden is a native of East Texas that makes a medium sized tree of good form. It is an excellent shade tree but requires considerable moisture.

BOIS D'ARC, OSAGE ORANGE (*Toxylon pomiferum*)—The bois d'arc is a tough tree, making a slow to average rate of growth. It has dark green lustrous leaves forming a broad rounded crown. The fruit is a nuisance but is only borne on pistillate or female trees. It is long-lived and although in youth it needs some pruning, yet it is a very desirable shade tree for the drier parts of the state, reaching its best development, however, along the Red River.

AMERICAN ELM (*Ulmus americana*)—The American elm is probably the best shade tree over a larger area than any other tree in this country. It is the pride of New England cities, and has proven its value in the Panhandle towns. It does best in rich moist loam but thrives remarkably well on dry alkali soils. It is not a fast grower but attains a great size and age—features desirable in shade trees. The elm develops a high spreading crown adapted to wide avenues. In some regions it is badly injured by scales, borers, and defoliating insects, but in Texas it is fairly free and not more susceptible than many less desirable trees. In the southern part of the state it suffers from the heat and loses its foliage early in the season, but in the northern and eastern sections this defect is not noticeable.

CEDAR ELM (*Ulmus crassifolia*)—A native tree with small leaves. It is smaller, and shorter lived than American elm. It becomes too bushy to be a good shade tree and should never be used where American elm can be obtained.

SLIPPERY ELM (*Ulmus fulva*)—The slippery elm is inferior to the American elm, being smaller and shorter lived. It has a poorer form than American elm but is a fair shade tree.

EVERGREENS—As a general rule evergreens are not desirable street trees but make excellent ornamental trees and with proper grouping give good mass results. Nearly all evergreens are difficult to transplant and show relatively slower growth than deciduous trees.

HIMALAYAN CEDAR (*Cedrus deodora*)—The Himalyan cedar is an Asiatic species which has light foliage resumbling that of the fir trees somewhat. It has the conical habit typical of most evergreens of the cedar, fir and spruce type. It grows rather rapidly and seems to stand a considerable amount of dry weather, making a very desirable conifer for this region.

CAMPHOR TREE (*Cinnamomum camphora*)—A Chinese broad-leaved evergreen of medium size which grows rather rapidly and makes an excellent street tree. This tree is the source of commercial camphor which is made by boiling chips of wood.

ITALIAN CYPRESS (*Cupressus sempervirens*)—This European tree is an excellent one for specimen planting but should be used sparingly. It is narrowly conical in form, thus furnishing little shade. The foliage is dark green, the cones golden brown and very showy.

ARIZONA CYPRESS (*Cupressus arizonica*)—A native of Arizona, this tree is a very handsome evergreen with silvery blue foliage. It makes a rather rapid growth and becomes a medium sized tree similar in shape to Italian cypress. It appears to stand drought pretty well, and for color effect it takes the place filled by blue spruce and white fir in the north.

RED CEDAR (*Juniperus virginiana*)—The red cedar and its western counterpart, SOUTHERN RED CEDAR (*J. barbadenses*), are both native in Texas. They are the commonest evergreens in Central and Western Texas. They make slow growth but are long-lived and will grow in very dry situations and do with very little attention.

HOLLY (*Ilex opaca*)—A very handsome East Texas broad-leaf evergreen with thick glossy leaves and conspicuous red berries. This tree makes a slow growth but reaches a fair size. It is pyramidal in youth but has a more rounded crown in later life. It is a good street tree when given plenty of room but is liable to suffer from vandalism.

MAGNOLIA, BULL BAY (*Magnolia grandiflora*)—This is a tall native evergreen with showy flowers. It makes a pyramidal head with a good branching system and tough, thick, lustrous leaves. It is an excellent lawn tree and a good street tree. Other magnolias are also used, principally UMBRELLA TREE (*M. tripetala*), CUCUMBER TREE (*M. acuminata*) and SWEET BAY (*M. glauca*).

BLUE SPRUCE (*Picea parryana*)—This is a very popular ornamental tree in the north but in Texas it makes very slow growth. Its blue green foliage and regular form, however, make it desirable in the Panhandle and at high elevations. It needs plenty of water and care. In general, Arizona cypress and Himalayan cedar will fill its place in Texas.

AUSTRIAN PINE (*Pinus austriaca*)—A European evergreen which makes a slow growth but stands drought and heat fairly well. It is a long-lived tree and a large one at maturity.

JACK PINE (*Pinus divaricata*)—A northern pine which grows rapidly during its youth. It makes a medium sized tree which does well in dry sandy regions.

LONGLEAF PINE (*Pinus palustris*)—The longleaf pine does well on very poor sandy soils. It is long-lived and becomes a large tree. Longleaf pine is a native of East Texas and has not been planted successfully west of the East Texas timber belt. It has an excellent form and is a good tree for the eastern part of the state.

SHORTLEAF PINE (*Pinus echinata*)—This native pine makes a satisfactory shade tree in East Texas and may be grown possibly west of Fort Worth and Waco, although very little planting of pines has been done in that region.

WESTERN YELLOW PINE (*Pinus ponderosa*)—This Rocky Mountain tree occurs naturally at higher elevations in Southwest Texas. It is a slow growing long-lived pine which needs a rather cool situation but thrives where the rainfall is very low. It does well at Amarillo.

SCOTCH PINE (*Pinus sylvestris*)—The Scotch pine is a European tree which stands low precipitation and poor sandy soil. It is moderately fast growing and long-lived. It should prove to be a valuable tree for West Texas.

LOBLOLLY PINE (*Pinus taeda*)—A native East Texas pine which extends farther west than its two associates, longleaf and shortleaf pine.

It is the fastest grower and has the best form of the three trees. Its western range can probably be extended somewhat but very little experimental planting with the pines has been done.

LIVE OAK (*Quercus virginiana*)—A magnificent broad crowned evergreen oak, native of Central Texas. It is a slow grower but reaches immense size and an old age. Because of its wide spreading crown it should be given plenty of room. It makes a very dense shade with its dark green glossy leaves.

ARBORVITAE (*Thuja occidentalis*)—A compact hardy tree with scale-like leaves and dry cones instead of the "berries" which are found on cedar. The twigs are flattened fan-like. The arborvitae grows moderately fast and makes a fair sized tree. It can be trimmed to any desired form. It appears to stand dry hot summers very well and makes a good hedge tree.

CHINESE ARBORVITAE (*Thuja orientalis*)—A Chinese tree similar to the above species but even hardier. Many nursery varieties of the arborvitae trees have been propagated, varying widely in size, form, and color.

OLIVE (*Olea europea*)—A medium sized broadleaf evergreen much used along the gulf.

Many varieties of palms and semi-tropical trees are being tried out along the coast and the exact limits of their ranges have not been determined.

A safe rule to follow is to plant what your neighbor has had success with. This is conservative, of course, and many other varieties may do as well or even better than those which are found in any particular locality. Nursery men are apt to be over-enthusiastic about new introductions or to describe unusual results as what could commonly be expected. It is well not to put too high hopes in unproven trees. On the other hand no one perfect shade tree has been discovered. Each has its good points and its poor ones. One tree is short-lived, another is hard to transplant, yet another is especially subject to insect attacks, and so it goes. The list given above might have been doubled or trebled without exhausting all the possibilities for planting in the state. There are 200 or more native trees in Texas, and the list of exotics which might be of value in some parts of the state is a long one.

PLANNING LOCATION

After selecting the proper variety of tree for the street in question the next point to be decided is the proper location of the trees and their proper spacing. The tendency is always to space trees too closely. This, of course, is due to the desire on the part of the planter to secure a maximum of shade in a minimum of time. This close spacing would be of minor importance—perhaps desirable from an aesthetic standpoint if the trees were thinned out as soon as they started to interfere. However, once the trees get large enough to interfere with one another they have assumed a place in the owner's affections which warps his good judgment. They seem to be too valuable to be cut out just now and are left for a few years longer. The result is that by the time they are removed the remaining trees have become crippled and have had their crown symmetry impaired. Parts of the crowns have been suppressed and the trees cannot recover even when the interfering trees are removed. Therefore, the safest thing to do is to space properly in the beginning. The distance apart will vary for different species and for the same species in different soils and climates. In East Texas and in rich bottom lands the trees will need ten to fifteen feet more room than in dry situations with poor soils. Trees suited to narrow streets should be spaced about thirty feet apart, those for medium width streets forty feet and those adapted to wide streets will need fifty or more feet of space when they are mature. Normally trees are planted abreast on opposite sides of a street, but where wide spreading trees are planted along narrow streets it may be advisable to alternate them. On lawns, trees are best planted informally in groups rather than in rows.

In no case should trees be placed at the corner of intersecting streets, since in such locations they are especially liable to injury by pedestrians or by teams and automobiles if there are no curbings. Furthermore, when the trees are young they will obstruct the view of vehicles and interfere with traffic.

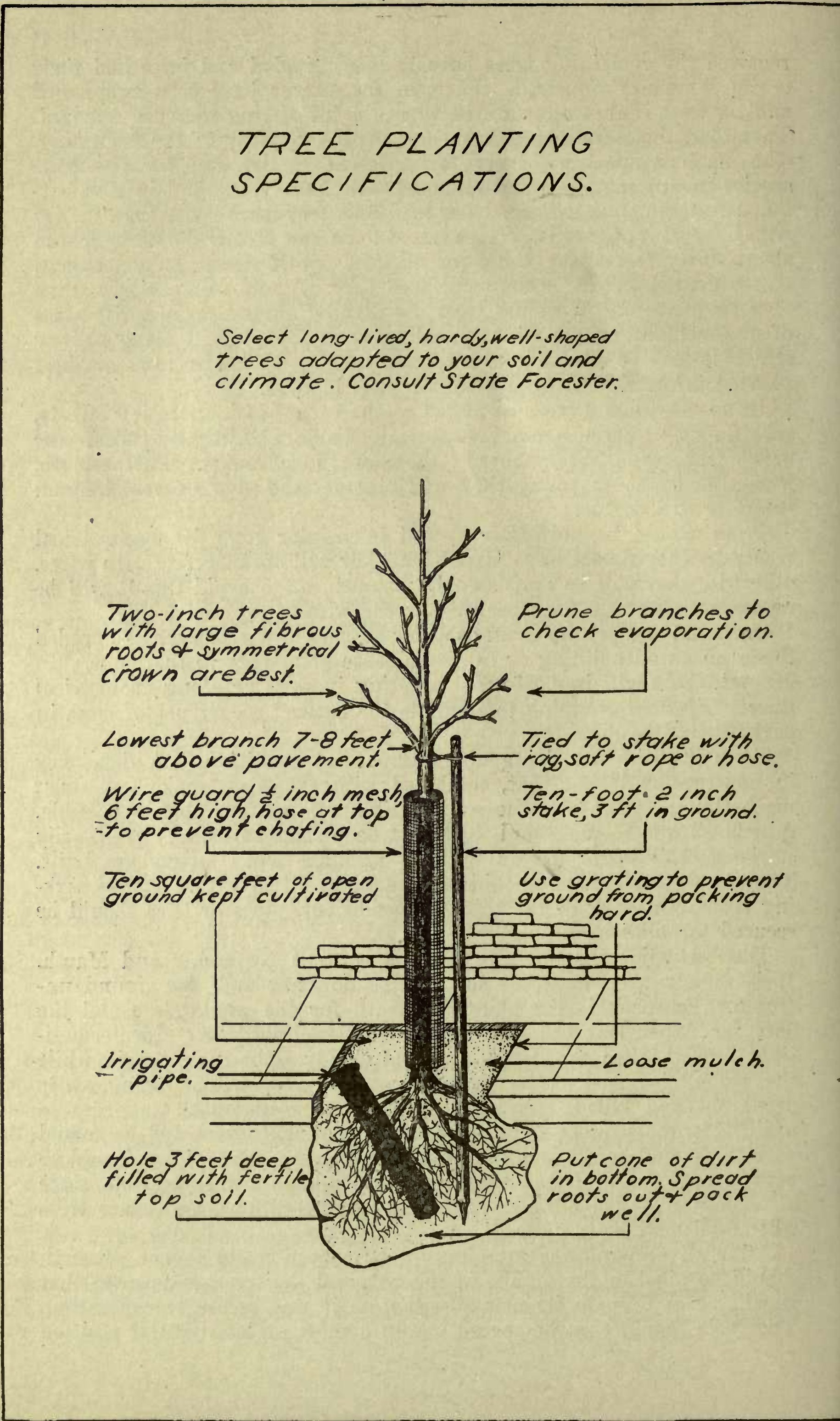
Trees should be uniformly spaced in regular rows for symmetrical results. They should be so placed that they will not interfere with wires, otherwise they will be mutilated by linemen, or to avoid this it will be necessary to cut the tops back below the wire.

On lawns and private grounds a row of trees or a group may be needed to screen an outbuilding or to give a sense of privacy to the home. In general, there will be no formal planting in rows or along geometrical lines. Informal grouping to simulate the natural occurrence of trees in parks should be done.

Trees in cities are living under unnatural conditions. A deficiency in moisture and sun light, combined with excessive smoke and dust, make it imperative that the soil conditions be as favorable as possible. A hole four feet square and three feet deep should be dug. Ordinarily sterile subsoil is thrown up to form parkings when streets are built. Therefore good top soil should be secured to fill in with. If the parking space is narrow or the rainfall insufficient, pipes or tiles should be secured for sub-irrigating.

The best time for planting trees is between November and March. It is merely necessary that the tree be dormant and the ground unfrozen. February is the planting month for the whole state and the date for Arbor Day has been well chosen—February 22. Ideal conditions prevail when the day is cool and cloudy right after a rain while the ground is moist. The feeding roots are very tender, being easily dried out and killed, especially the roots of evergreens. In order to avoid this, roots ought to be "puddled"; that is, they should be coated with thick mud before being taken to the planting site. They should be kept covered and protected from sun and wind as much as possible, since an exposure of five minutes is fatal to pine seedlings, and other trees will stand very little more.

After all preparations for planting have been made a cone of earth should be piled in the middle of the hole and the tree set down so that it will be as deep in its new situation as it was before transplanting. The roots should then be spread out in a more or less natural position



TREE PLANTING SPECIFICATIONS.
Select long-lived, hardy, well-shaped trees adapted to your soil and climate. Consult State Forester.
Two-inch trees with large fibrous roots & symmetrical crown are best.
Prune branches to check evaporation.
Lowest branch 7-8 feet above pavement.
Tied to stake with rag, soft rope or hose.
Wire guard ½ inch mesh, 6 feet high, hose at top to prevent chafing.
Ten-foot 2 inch stake, 3 ft in ground.
Ten square feet of open ground kept cultivated
Use grating to prevent ground from packing hard.
Irrigating pipe.
Loose mulch.
Hole 3 feet deep filled with fertile top soil.
Put cone of dirt in bottom. Spread roots out & pack well.

and the dirt piled in slowly and packed down well around them. Care should be taken that no large stones or pieces of dry roots, bark, wood or grass come in contact with the roots to cause air spaces, since these cause the roots to dry out. The top layers may have some rocks and coarser dirt, but the better the earth the better the tree growth. The last dirt to be thrown in should not be packed, and over it some loose hay should be spread to act as a mulch.

SUBSEQUENT CARE

All nursery stock is pruned before it is received from the dealer, but when unpruned deciduous trees are received they should be cut back in order to balance the shock caused by the failure to get the whole root system. Evergreens, especially conifers, such as pines, spruce and fir, cannot be pruned, which accounts somewhat for their higher mortality at planting time. The diagram on page 24 illustrates correct pruning and planting. If the planted sapling is to develop into a desirable ornamental tree it must be given considerable attention and care. It is not advisable to water trees very frequently, but when they are watered a thorough job should be done. Frequently a mound of dirt around the tree will be enough to make this possible. Three inches of water can be easily turned in and will gradually soak down to the roots. Surface irrigation tends to draw the roots to the surface, however, and makes them susceptible to slight droughts, while sub-surface irrigation will prevent this largely by attracting the roots to the water level. A good thorough watering every ten days in dry weather should be sufficient for even those trees which require considerable soil moisture.

Even more important than irrigation is cultivation. Frequent cultivations during the growing season is a great benefit to a tree. Weeds and grass sap the moisture and fertility from the soil and must be kept down. A space at least four feet in diameter must be kept clean and mulched.

Only a few trees develop naturally into the desired form. Most trees become twiggy, bushy, or straggly. They need pruning or training in order to direct the growth into those branches which will give the tree a symmetrical appearance. Pruning is also essential for the removal of dead, diseased, or injured limbs.

Dead limbs may be removed at any time, but live limbs should be cut during the winter if possible. They may be cut at other seasons, but during early spring, pruning will cause the tree to "bleed" and will injure it somewhat, while late summer pruning may stimulate growth and make the new shoots liable to frost injury.

In pruning it is desirable to maintain the natural form of the tree, merely removing limbs where they are too thick or raising the head by removing branches on the under side of the lower limbs.

The weight of large limbs will often cause them to split and rip the bark when a straight cut through from the upper side is attempted. The safest way to prune is to make three cuts as shown in figures on page 28. The first or undercut prevents the limb from splitting past where the final cut is to be made. In all events the cut must be made as nearly flush with the main or parent limb as can be. No stub should be left isolated from the flow of sap to ultimately harbor rot and weaken the tree.

Evergreens should be pruned very sparingly. Dead or dying limbs must be removed, of course, and occasionally a limb should be taken off to prevent a crown from becoming one-sided. Lower limbs should not be removed from small trees as a general rule, as this spoils the symmetry of the tree and makes them top heavy. This is true of the conifers, but the broadleaf evergreens, like live oak and magnolias, may be handled like the deciduous trees.

It is highly desirable to use fertilizer to maintain the food materials in the soil. Too often trees are starved to death. Commercial fertilizer should be applied rather sparingly since it is easy to get too much and thus injure instead of benefit the tree.

TREE TROUBLES AND REMEDIES

City trees are subject to many injuries, diseases and insect attacks due to their unnatural surroundings. They must be carefully watched and kept in as thrifty a condition as possible so that they may be resistant to a great extent or able to recover quickly in case they do suffer some reverse.

INSECTS

Insects are the bane of a tree's existence in the forest and even more so in the city where natural parasites are lacking and birds are relatively scarce. The insects which attack trees may be classed under three general heads according to their various feeding habits. These three classes are known as sucking insects, borers, and defoliators. Each class must be combated in a different manner.

The sucking insects include scales, mealy bugs, and plant lice. They feed on plant juices through sucking mouth-parts. Scales are minute hard-bodied flat or slightly convex insects which fasten themselves closely to the trunk, twigs, or leaves, and usually are unable to move around after they assume the adult form. The younger stages of scale insects may fly and migrate, however. The oyster shell scale is a well known example of this class of insects. Another is the cottony maple scale, which is much larger than most of the scales and which secretes a mass of white waxy threads. Mealy-bugs are soft-bodied small insects which are characterized by the waxy, cotton-like covering which they exude. Citrus mealy bugs attack many orange trees in this state. Plant lice are soft-bodied insects, too well known to require further description. They feed only on young tender shoots and are often found injuring willow and poplar.

Scales.—Since the control methods are essentially the same for all scales they will be considered as a group. They are best combated in winter, since stronger sprays may be used and more satisfactory results obtained.

Lime-sulphur is the most useful spray against scale insects, and, furthermore, it has some value as a fungicide. Lime-sulphur may be secured ready made, needing only dilution to be ready for use. Usually 10 per cent stock solution to 90 per cent water will give satisfactory results. Lime-sulphur may be made at home if desired but the commercial product is preferable.

FORMULA FOR LIME-SULPHUR SPRAY

Unslaked lime 40 lbs., flowers of sulphur 30 lbs., water 100 gallons.

Heat the water, and to one-half the quantity add the lime. The slaking lime will boil the water, to which the sulphur, mixed as a paste with a little water, should be added and the whole stirred. Finally add the rest of the water and strain before using in the sprayer.

Another good remedy is kerosene emulsion prepared as follows:

KEROSENE EMULSION

Whale oil soap ½ pound, kerosene oil 2 gallons, water 1 gallon.

Boil water, dissolve soap and add kerosene, pumping vigorously until the oil goes into emulsion, forming a creamy stock solution, which should be diluted with fifteen to twenty times its bulk of water for use in summer spraying for soft-bodied insects.

Some miscible oils are on the market which do not require hot water or strenuous pumping before being ready for use.

Mealy bugs should be sprayed with kerosene emulsion or with carbolic acid solution, which is prepared as follows:

CARBOLIC ACID EMULSION

Whale oil soap 40 pounds, crude carbolic acid 5 gallons, water 35 gallons.

Heat the water and add the soap. After it is dissolved add the acid and boil for twenty minutes. Use twenty parts of water to one of the stock emulsion. This is good for soft scales and plant lice as well as mealy bugs.

Plant Lice. These insects multiply very rapidly and do severe damage to the tender growing parts of trees. They should be sprayed with carbolic acid emulsion, kerosene emulsion, or soap wash.

SOAP WASH

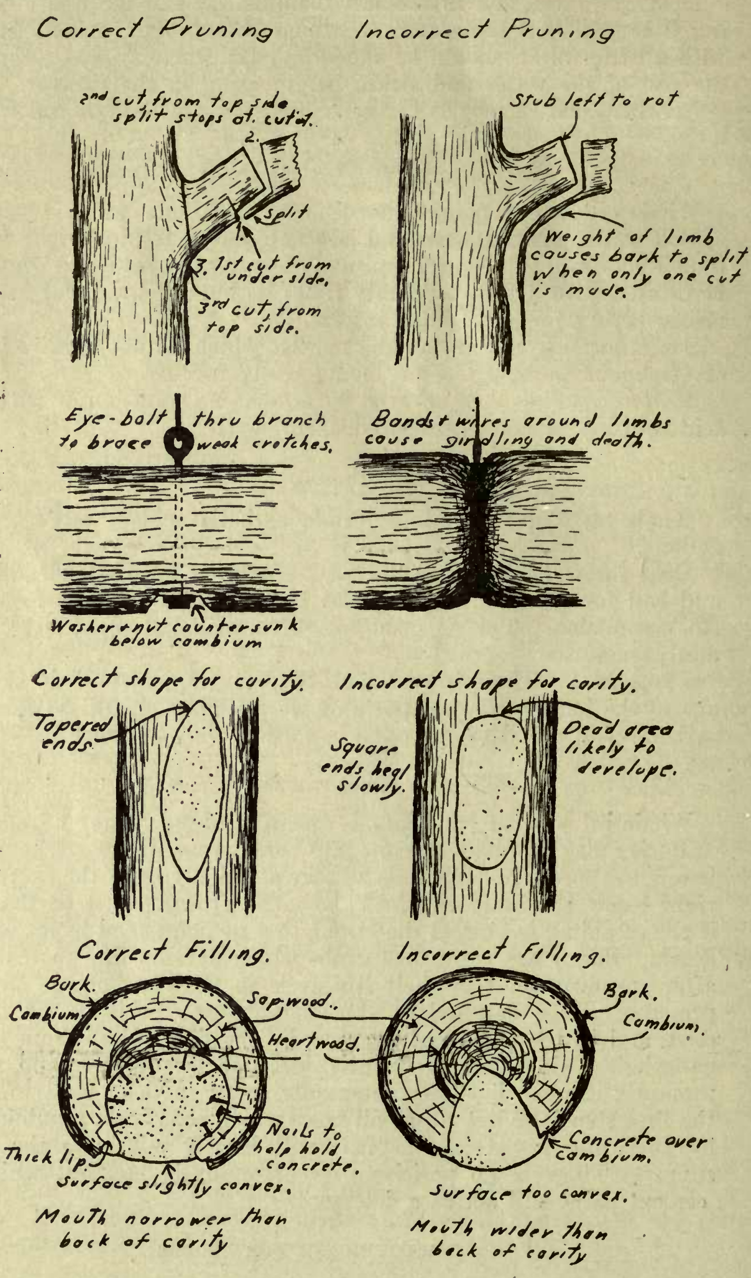
Whale oil soap or hard laundry soap 1 pound, water 5 gallons.

Borers may be divided again into bark borers and wood borers. Bark borers are specially dangerous as they attack a tree in the cambium layer right below the inner bark. This is the growing part of the tree, and if the cambium is girdled the circulation of plant food is cut off, causing death. Borers are worm-like grubs which develop into moths or beetles after spending most of their life cycle in the bark of the tree. Their presence can be detected by the entrance or exit holes, by the boring dust, and in the spring of the year by the flow of sap from the boring galleries. Bark-borers frequently kill out large trees, and should be promptly combated. They commonly breed in dead or dying trees, so the first step is to get rid of all trees which constitute a public nuisance by harboring insect pests. This will largely eliminate the source of supply. There is no positive preventive for borers, but whitewash or cement paint will act as a deterrent.

WHITEWASH FOR BORERS

Quick lime 3 pounds, caustic potash 2 ounces, crude carbolic acid, 1 ounce, water 2 gallons.

TREE REPAIR


Correct Pruning
Incorrect Pruning
2nd cut, from top side split stops at cut 1.
2.
Split
1.
3. 1st cut from under side.
3rd cut, from top side.
Stub left to rot
Weight of limb causes bark to split when only one cut is made.
Eye-bolt thru branch to brace weak crotches.
Washer + nut countersunk below cambium
Bands + wires around limbs cause girdling and death.
Correct shape for cavity.
Tapered ends.
Incorrect shape for cavity.
Square ends heal slowly.
Dead area likely to develope.
Correct Filling.
Bark.
Cambium.
Sap-wood..
Heartwood.
Nails to help hold concrete.
Thick lip.
Surface slightly convex.
Mouth narrower than back of cavity
Incorrect Filling.
Bark.
Cambium.
Concrete over cambium.
Surface too convex.
Mouth wider than back of cavity

CEMENT PAINT

Portland cement, skimmed milk. Add enough milk to reduce the cement to the consistency of thick paint.

Either of these two applications should be painted on the trunk and larger branches as far up as the insects are likely to attack, usually ten or twelve feet. If the bark is rough and scaly it should be smoothed off first. Cement paint is good for one whole season, but whitewash should be applied twice during the growing season for best results.

It is very difficult to eliminate borers once they have obtained a foothold. The individual boring holes must be probed with wires or saturated with carbon bisulphide (high life) squirted in with an oil can, after which the hole must be plugged up with clay, putty, or some other handy material. The third alternative is the obvious one of gouging out the holes until the worm is found and killed.

Wood borers are found boring through the heart and sap wood of healthy, dead, and dying trees. They are only slightly less dangerous than bark beetles, causing the death of many large veteran trees and often weakening the limbs of others so much that they are readily broken off in a heavy wind. They may be controlled to some extent by the same means that are used against bark borers, mentioned above.

Defoliating insects are easy to control but if left unmolested the stripping of the leaves will seriously weaken the tree. Three successive defoliations will usually kill a deciduous tree, while one complete defoliation may kill coniferous evergreens, which are not very resistant to the attacks of these insects.

It is sometimes practical to creosote egg-clusters or to collect the nests and burn them, but the usual way to attack this class of insects is to spray the foliage on which it feeds with arsenate of lead, which can be procured in any town. Two and one-half pounds of poison to forty gallons of water is the strength commonly used.

Red spiders are best controlled by lime-sulphur dust, which is a powder composed of equal parts of flowers of sulphur and dehydrated lime.

Banding is occasionally useful, to prevent insects from crawling up trees. Such insects as the bag-worm, the female of which cannot fly, may thus be prevented from gaining access to trees already free from their attacks.

BANDING MIXTURE

Resin 16 pounds, castor oil 1 gallon.

Heat until the resin is melted, then dip ropes in the mixture. The ropes, covered with the banding compound, should then be tied around the trees about four or five feet above the ground and renewed every ten days or oftener if the mixture begins to dry and harden.

FUNGI

The next most important cause of injury to shade trees is fungus or rot. Fungus diseases come under six heads: heart rot, sap rot, root rot, canker, bark diseases, and leaf blight.

Heart rot commonly occurs in old trees, which may be so badly affected that the heart wood is entirely disintegrated, leaving the hollow tree to be supported by the outer shell of bark and sap wood. Since the heart wood of the tree is dead wood its only function can be to brace and support it. Accordingly the removal of the heart wood does not necessarily result in the death of the tree. Death in such cases may result from windbreak. Heart rot gains access to a tree through branch stubs, through roots, or through deep scars and injuries. It often gets a start in street trees through the dying back of a stub in the top caused by poor pruning at the time of planting and subsequent neglect. It is common practice to top back forest grown trees to a point where the main stem is from one inch to three inches in diameter. The new growth is apt to start several inches below the cut, thus allowing the end to die and become infected. Such dead ends should be removed and the scar painted.

Sap rots usually result from the spread of heart rots or occur in dying trees. They are serious since the function of the sap wood is to serve as a transporting medium for the food material from which the wood cells are built. By killing out this layer the circulation of sap is interfered with and if the rot extends completely around the tree the host may be killed.

Heart and sap rots are prevented by careful pruning, followed by covering the wounds with paint, tar, or creosote. All insect galleries serve as a point of access for fungus spores. Such holes should be drained and painted.

There are three methods of treatment for cavities and diseased places in shade trees. They are called the open cavity, cement filling, and asphalt filling treatments. At the present time the tendency is to do as much open treatment as possible.

Excavating Rots. In repairing a tree affected by rot the first step is to bore in at several places to locate the exact extent of the rot. It may be feasible to excavate from one hole entrance or again two or more may be needed. In cutting out decayed wood it is essential that all the rot be removed. The so-called "rots" often extend several inches into apparently sound healthy wood. It is frequently impossible to tell whether the decayed portion has been entirely cut out, but if the cavity is left open a subsequent examination will clear up all doubts.

Excavating Tools. A mallet, a half round gouge, and two or three chisels of various sizes are handy tools for this work. Large cavities may be opened to advantage with hand axes. After all the decayed part has been removed the bottom of the cavity should be provided with drainage to prevent water from standing there. It is not essential to have the walls absolutely smooth, but they should not have large crevices that may harbor insects. The mouth of the cavity should be made regular, and where possible the shape should be oval, tapering toward the top and bottom. This type of hole heals over quickest, while square ends often result in dead areas adjoining the hole due to the failure of the sap to properly nourish them.

Painting. There are several good covering substances on the market for painting over wounds. The creosote compounds penetrate well and act as antiseptics. Tar is good, and roofing or asphalt paints are very satisfactory. Ordinary house paint is better than nothing, but is apt to crack, affording an opening for moisture and disease spores. Carbolineum is an excellent antiseptic paint.

Sheet Metal. A modification of the open cavity treatment is the use of sheet metal nailed across the cavity opening. In such cases the bark and the cambium layer, which is the growing part of the tree just below the bark, should be cut back to form a shelf to which the metal is nailed. It is necessary to have the metal shaped to the opening and care must be taken that it does not overlap the cambium or bark anywhere since then the new wood would work in under and pry it up instead of closing in over it. The open cavity treatment or this modification of it is useful for very large cavities and where stress or bending might cause asphalt or concrete to crack.

Asphalt Filling. The asphalt method is used for openings where little bending occurs or for relatively small holes. The cavity is cleaned out and prepared just as for the open treatment. The mixture used is about one part of asphalt (heated) to six parts of sand or sawdust. This mixture is packed in with a trowel behind a metal front.

Concrete Filling. The concrete method of filling cavities is restricted to small holes or ones at the base of the tree where there will not be much bending. The preliminary steps are identical with those undertaken before using asphalt. After the walls of the cavity are painted with tar or carbolineum, nails or iron braces are fastened to them to help retain the concrete. It is necessary to have the cavity wedge-shaped. smaller at the mouth than at the back in order to retain the cement properly. (See diagram, page 28.) The filler is one part of Portland cement to three parts of coarse sand or gravel. If the dry method is used then only enough water is added to make the mixture capable of being molded. It must then be packed in solidly and tamped. If the wet method is used a sack or cloth must be nailed across the mouth of the cavity and the soft concrete filled in behind it. Before the cement has entirely hardened the sack should be taken off and the edges of the cement trimmed back below the cambium. The cement must not be allowed to bulge at the mouth. It should be flat or very slightly convex if the wood is to heal over it properly. A waterproofing concrete paint should be used to exclude moisture from the filler.

Root rots are caused by disease organisms which spread through the soil and are very difficult to combat. The common cotton root rot and others closely allied may cause large trees to wilt and die within a few hours. There seems to be no practical remedy for such diseases and little or no forewarning that they are present and threaten to do damage. Where a tree has been killed by root rot no other tree should be planted in that location since the disease is in the soil and new trees will almost certainly be attacked.

Bark Diseases. Canker and bark diseases are common on poplar and many other trees. All diseased bark and wood should be cut out and the wound treated with creosote.

Blight. Leaf blight and leaf spot diseases are caused by mildews, and may be controlled by spraying with a good fungicide like Bordeaux mixture or lime-sulphur wash. (See page 27.) Bordeaux mixture may be purchased ready made but cannot be made up at home to good advantage owing to the rather expensive apparatus needed for preparing it. Raking and burning all fallen leaves will greatly assist in the control of diseases affecting the foliage.

WEATHER INJURY

Dry weather injury can be minimized by frequent cultivation and occasional thorough irrigations, preferably through pipes or tiles sunk around the roots of the trees.

Sun scald causes the bark on the south and west sides of young, thin-barked trees to die and crack off. This may be avoided by wrapping burlap around the trunk or by using wood veneer guards. Where this injury has occurred the loose bark should be removed and the wound painted.

Wind and snow often cause large limbs to split off. Such injuries should be smoothed over and painted. Care should be taken that no place is left in which water can accumulate. Splits may be prevented by bracing any limbs which have weak crotches. The best way is to use eye bolts through the limbs two to six feet above the crotch and connect them with a strong wire cable. In using bolts, the hole where the head and washer come should be counter sunk below the cambium and later filled with asphalt.

MISCELLANEOUS INJURIES

Street trees are very apt to be injured by horses. Where this danger exists the tree should be protected by iron or wooden guards made large enough to avoid strangling the tree. Frequent examinations are necessary to insure that the tree is not being girdled by the guard.

Where parking spaces are small or where the ground may be tramped down solidly there is danger that there will be insufficient soil moisture and a deficiency of air for the roots. The use of grills or gratings around the base of these trees will provide better ventilation and will permit more moisture to reach the roots.

Escaping gas, ice cream salt, smoke, grade changing, and many other causes are responsible for tree sickness in cities. When in doubt write to the State Forester for advice.

THE BEST TREES FOR TEXAS

(See map, page 6.)

For East Texas the best trees for shade are American elm, water oak, willow oak, burr oak, sycamore, sweet gum, pecan, and white ash. Only slightly less valuable are sugar maple, black walnut, tulip tree, overcup oak, Spanish oak, Texan oak, and hackberry. Of the evergreens the best are live oak, holly, magnolia, longleaf pine, shortleaf pine, loblolly pine, and Himalayan cedar.

In Central Texas the best trees are hackberry, American elm, sycamore, water oak, willow oak, burr oak, Texan oak, and pecan. Next in importance come green ash, white ash, overcup oak, Spanish oak, box elder, black walnut and mulberry. Of the evergreens red cedar, Himalayan cedar, Arizona and Italian cypress, loblolly pine, and live oak are best.

In South Texas the most satisfactory shade trees are hackberry, black walnut, mulberry, and pecan. Of the other trees which grow there, box elder, silver maple, pomegranate, yucca, palmetto, loquat, and mesquite are fair. Olive, camphor, live oak, red cedar, and Arizona cypress are the best of the evergreens.

Southwest Texas has a climate and soil not adapted to tree growing. Irrigation is needed in any event. With some attention and occasional waterings honey locust, black locust, cottonwood, silver poplar, and salt cedar do well. Umbrella china, mulberry, silver maple, box elder and Russian olive rank next in value. Of the evergreens red cedar, Scotch pine and Arizona cypress grow well. It is probable that others will be found suited once they have been tested.

In the Panhandle the most desirable trees are black locust, honey locust, American elm, green ash, and silver maple. Closely following this group come box elder, Russian olive, silver poplar, bois d'arc, and hackberry. Scotch pine, jack pine, western yellow pine, red cedar, Himalayan cedar, and Arizona cypress do well among the evergreens. Below the caprock umbrella china, catalpa, and paper mulberry make good shade trees.

Almost as important as climate in determining tree distribution is soil types. The tables on pages 7 to 11 give more specifically the situations and localities in which the several species will grow and make satisfactory trees.

THE CITY FORESTER

Every large Texas city should have a City Forester to handle the selecting, procuring, planting, cultivating, spraying, trimming, and preserving or removing of all trees in the city streets. The smaller cities and towns may handle this work through some civic organization or tree club composed of enthusiastic interested parties.

The City Forester and the board under which he works should be free from political influences. This is particularly essential because of the character of the work which deals largely in the future. Results are not always apparent in a year's time and the City Forester should be protected from political whims until he can carry out his policies. He should be appointed by the board of city development or park board and should work under its direction. Since a City Forester must deal with people, must be a good talker and a good mixer, must know trees, insects and diseases and how to treat them, must know the principles of landscaping and must be versed in repair work, it is apparent that he must be trained for the work. He should have the ability to organize community clubs, to address schools, and to prepare articles for the press. Several cities have already called on the State Forester for assistance in securing a capable, trained, technical man, and he will be glad to put other cities in touch with men.

All tree work should be regulated by the City Forester and suitable ordinances should be passed giving him authority to properly handle the work and enforce the regulations.

The following regulations may serve as a guide:

1. The board of (insert name) shall have full power and authority over all trees planted and to be planted in any of the streets or public places of the city, including the right to plant new trees and to care for the same, and to trim, spray and otherwise care for such trees, and to remove trees, living or dead.

2. The board of (insert name) is authorized to appoint a City Forester and such other employes and assistants as may be necessary, and to prescribe and define their respective duties and to fix the amount of their compensation. Such Forester shall be an expert, trained in the care and culture of trees.

3. The board of (insert name) shall recommend to the (insert name of civic legislative body) from time to time, ordinances to be enacted

by the said (insert name of civic legislative body) for the planting, care and protection of trees in the streets and public places of the city; but no such ordinance not recommended by the said board shall be enacted by the (insert name of civic legislative body). Nor shall any ordinance enacted pursuant hereto be altered or repealed without the recommendation of said board.

4. The (insert name of civic legislative body) shall, every year, grant to the board of (insert name) such sum of money as it shall require and as to the said (insert name of civic legislative body) shall appear reasonable and just, for the planting, maintaining and caring for the trees of the city, for purchasing or raising new trees, and for other expenses contemplated by Sections 1, 2, 3 and 4 of this act.

5. No person shall, without the written permit of the board of (insert name) cut, remove, plant, break or injure any tree, plant or shrub in any of the streets or public places in the city of (insert name). Nor shall any person injure, misuse, or remove any device placed and intended to protect any tree, plant or shrub in any part of the streets or public places of the city of (insert name). Nor shall any person fasten a horse to any tree, plant or shrub, or to any device intended to protect the same, or place a post for the hitching of horses within five feet of any tree, plant or shrub in any of the streets or public places of the city of (insert name).

6. No building material or any other material of any description shall be piled up against any street tree unless said tree is first sufficiently protected by a proper guard to prevent possible injury, and all instructions issued for that purpose by the board of (insert name) must be promptly complied with by the owner.

7. The board of (insert name) shall have power to remove any wire conduit or other thing that burns, cuts or chafes any part of any tree, whether trunk, root or branch, in any street or public place, in case the owner of the wire shall fail after three days' written notice to take adequate steps to prevent further injury.

8. No paving of any description shall be laid or maintained by anyone between the sidewalk and the curb which shall cut off the air and water from any tree.

Local conditions will dictate what other ordinances will be needed in order to adequately protect the city trees.

For the convenience of persons who desire to secure trees the following list of nurserymen is given. This list includes those dealers who grow shade trees and general nursery stock. There are also a number of out-of-state nurserymen who do business in Texas.

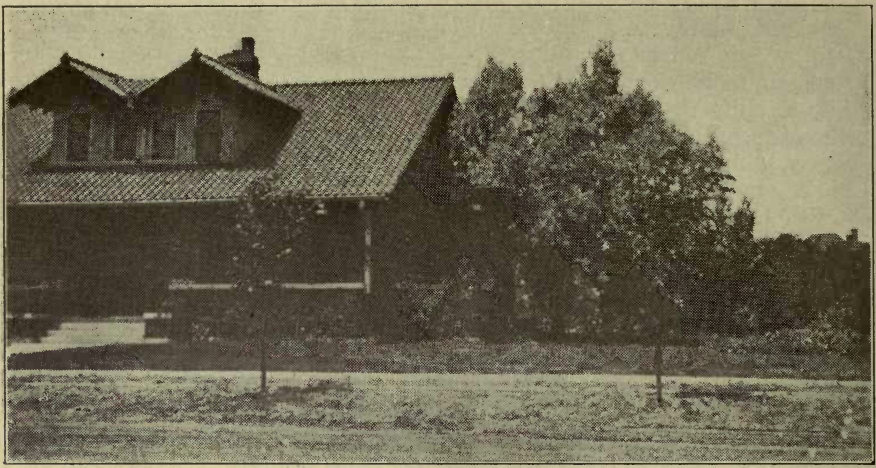
TEXAS NURSERY DEALERS

Name of Firm.	Postoffice.
Adams, H. J	Cibolo
Allen, J. H	Friendswood
Allen Bros.	Pottsboro
Alleshouse, M. L	Arcadia
Alvin Japanese Nursery	Alvin
Alvin Plant Farm	Alvin
Arlington Nursery	Arlington
Austin Nursery Co	Austin
Aylesworth, D. C	Plainview

Name of Firm.	Postoffice.
Baker Bros. Co	Fort Worth
Barnes, H. W	Pittsburg
Barthlome, A	Corpus Christi
Birdsall, A. D	Almeda
Black's Nursery	Mt. Pleasant
Bonham Nursery	Bonham
Brown Nursery and Floral Co	Dallas
Bruce, A. L	Clarendon
Caldwell, W. H	Corpus Christi
Campbell, L. I	Dallas
Carr, T. F	Bay City
Cluck, J. W., & Son	Dallas
Clyde Nursery Co	Clyde
Cole, Robert F	Dallas
Comal Springs Nursery	New Braunfels
Cooke County Nursery	Gainesville
Cowell, L	Fort Worth
Crutchfield, Wm.	Vernon
Daingerfield Nursery	Daingerfield
Dallas Shade and Fruit Tree Co	Dallas
Delling, Otto	Dallas
Denny, J. W	Smithfield
Draper, A. N	McAllen
Drumm Seed & Floral Co	Fort Worth
Dubbs, C. W	Clarendon
Eagle Lake Nursery	Eagle Lake
Ecles, J. D	Vidor
Edgewood Nursery	Dickinson
El Campo Nursery	El Campo
Erath County Nursery	Dublin
Euless Nurseries	Arlington
Evergreen Cemetery	El Paso
Evergreen Nursery	Hawkins
Excelsior Nursery	Palacios
Figge, O. C	Beaumont
Fitzgerald, J. E	Stephenville
Ford, Sam P	Tyler
Forest Nursery	Fort Worth
Foster Nurseries	Denton
Frankston Nursery	Frankston
Goldthwaite Nursery	Goldthwaite
Griffing Nurseries	Port Arthur
Griffing's Delta Nursery	San Benito
Hannah, H. O., & Son	Sherman
Harris, A. J., & Son	Grand Saline
Hart's McAllen Nursery	McAllen
Henderson Nursery	Athens
Hendrix & Glass	Farmersville
Hereford Nursery Co	Hereford
Herrle, J. J. A	Houston
Hicks & Culver	Mt. Pleasant

Name of Firm.	Postoffice.
Hillsboro Nursery Co	Hillsboro
Hoffman, R. H	Denton
Holbert, Chas. E	Arcadia
Holbert, Mrs. R. W	Arcadia
Howard's Montopolis Nursery	Austin
Iron Ore Nursery	Denison
Johnson Orchard & Nursery Co	Dallas
Johnson, Bart	Comanche
Kaufman County Nursery	Terrell
Kearney, S. W	San Antonio
Kerr, Jno. S	Sherman
Kezer, H. A	El Paso
Kieswetter, A. H	Houston
Kirby, S. B	Bullard
Kirtly, C. C	Cameron
Lampasas Nursery Co	Lampasas
Lang Floral & Nursery Co	Dallas
Laredo Nursery Co	Laredo
Lewis, S. G	Lufkin
Lloyd, L. J	Nursery
MacDaniel, W. F	San Augustine
McGinney Nursery Co	Tyler
McKee Nurseries	Mt. Selman
MeKee, The J. E., Nursery Co	Texarkana
McKee, S. R., Nurseries	Jacksonville
McKinney Nursery Co	Dallas
Martin, W. M	Handley
Mary Austin Nursery	Alta Loma
Mignon, E.	Navasota
Moore Nursery Co	Tyler
Moss Bros.	Hico
Mosty, L. A., & Son	Center Point
Munson Nurseries	Denison
Myrtle Springs Nursery Co	Wills Point
Northeast Texas Nursery	Pittsburg
Oak Grove Nursery	Denison
Palacios Nursery Co	Palacios
Pearfield Nursery	New Ulm
Pilot Point Dewberry Farm	Pilot Point
Pine Springs Nursery	Tyler
Plainview Nursery Co	Plainview
Planters Nursery	Denton
Pomeroy, Eltweed	Donna
Potter Floral Co	El Paso
Riverside Nursery	Fort Worth
Rockdale Nursery	Rockdale
Rosedale Nursery	Brenham
Rosedale Nurseries	El Paso
Rose Hill Nursery Co	Texarkana
Rusk County Nursery	Henderson
Saibara, K.	Webster

Name of Firm.	Postoffice.
Saltillo Nursery Co	Saltillo
Samford, A. M.	Tyler
San Angelo Nursery Co	San Angelo
San Benito Nursery Co	San Benito
Sinton Nurseries	Sinton
Shamburger Nursery	Tyler
Shary, John H	Mission
Shell, C. L	Georgetown
Smith County Nursery Co	Tyler
Stephenson, H. F	Brownsville
Steinbring, S. W	New Braunfels
Stockwell Nursery	Alvin
Stone, Mrs. E. E	Dickinson
Sulphur Springs Nursery	Sulphur Springs
Teas Nursery Co	Houston
Terrell Nursery Co	Terrell
Texas Nursery Co	Sherman
Texas Rose Garden	Rockdale
Thomas, J. E	Atlanta
Thompson, J. M	Waco
Verhalen, Geo. F	Scottsville
Volz, Chas.	Mission
Waco-Tyler Nursery Co	Waco
Waxahachie Nursery Co	Waxahachie
Wahrli, Robert	Dallas
Western Home Nursery	Weatherford
West Tyler Nursery	Tyler
Whall, Walter	San Antonio
Wichita Floral & Nursery Co	Wichita Falls
Wright Nursery & Floral Co	El Paso
Wright, A. P	Mission



Russian mulberry in West Texas and the Panhandle makes a fast growth and is very hardy as well. The silvery foliage makes this a very desirable ornamental shade tree. This tree is in Amarillo, Texas.

Young green ash in the foreground and Carolina poplars behind in the forest tree nursery at the Denton Experiment Station. Some scores of new trees are being tried out each year at these stations to determine those suited to Texas conditions.

LIST OF BULLETINS ISSUED BY THE STATE FORESTER

Copies may be secured free of charge from the State Forester, College Station, Texas.

Bulletin 1. Grass and Woodland Trees. (Supply exhausted.)

Bulletin 2. Tree Planting Needed in Texas.

Bulletin 3. General Survey of Texas Woodlands, Including a Study of the Commercial Possibilities of Mesquite.

Bulletin 4. First Annual Report of the State Forester. (Supply exhausted.)

Bulletin 5. Forest Resources of Eastern Texas.

Bulletin 6. Forest Fire Prevention in Co-operation with the Federal Government. (Supply exhausted, replaced by bulletin No. 9.)

Bulletin 7. Farm Forestry. (Extension bulletin.)

Bulletin 8. Second Annual Report of the State Forester.

Bulletin 9. Forest Fire Prevention in East Texas.

Bulletin 10. Farm Forestry in the Shortleaf Pine Section of East Texas.

Bulletin 11. Shade Trees in Texas Towns and Cities.

Bulletin 12. Forestry Questions and Answers.

1. TREES INCREASE THE VALUE OF YOUR PROPERTY.

2. TREES PROTECT YOUR HOME AND YOUR STREETS FROM THE HEAT OF THE SUN.

3. TREES PROTECT YOU FROM THE COLD WINDS OF WINTER.

4. TREES GIVE OFF OXYGEN, THUS PURIFYING THE AIR.

5. TREES AFFORD AN ATTRACTIVE SETTING FOR YOUR HOME.

6. TREES MAKE YOUR CITY MORE LIVEABLE AND LOVEABLE.

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UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 176

NURSERY AND ORCHARD INSECT PESTS

L. HASEMAN

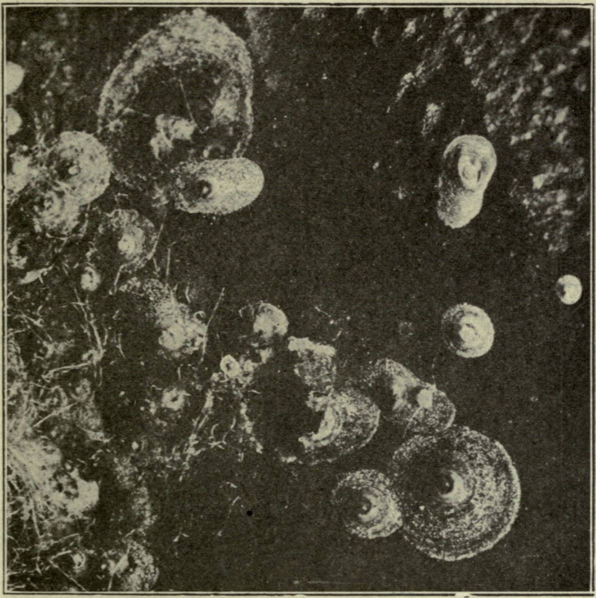

FIG. 1.—San Jose Scale; much enlarged, showing different stages of development

COLUMBIA, MISSOURI

OCTOBER, 1920

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

[1]In service of U. S. Department of Agriculture.

[2]On leave of absence.

Nursery and Orchard Insect Pests

Since the establishment of the Plant Inspection Service by the Legislature in 1913 the work of control of nursery and orchard insects has been given special attention. The San Jose scale, which since the early 90's has been responsible for much of the loss and damage to the fruit industry of Missouri, was taken in hand first of all. Remarkable results have already been secured in eliminating this pest from the nurseries of the state as well as from the important orchard centers. The various other less well-known insects and plant diseases have also received attention.

Except for certain pests of the fruit itself, practically every pest that is of importance in the nursery on the young trees, also attacks the older bearing trees in the orchard. For this reason it has seemed advisable in this report to deal with the various pests and their control both in the orchard and in the nursery. For the same reason it is of vital importance that the Plant Inspection Service be maintained and that adequate provisions be made to effectively protect Horticulture and Agriculture against future losses from insects and plant diseases. The problems of the fruit grower and nurseryman, in this respect, are identical, and to make the work most effective we must continue to have close cooperation between them. A neglected orchard will endanger a neighboring nursery as well as increase the difficulties of nearby fruit growers.

In this report the pests of apple, peach and other fruits will be taken up separately. Where a pest is of importance both in the orchard and nursery it will be so considered.

INSECT PESTS OF THE APPLE

Apple insects may be conveniently discussed as those of the roots, trunk and limbs, foliage and fruit. This method makes it easy for a fruit grower or nurseryman quickly to analyze his trouble.

Apple Root Insects

In Missouri there is only one insect of importance on the roots of apple trees. This is the Root Louse or Wooly Aphis, (*Schizoneura lanigera*). It is quite generally distributed thruout the state, breeding commonly on apple, haw, crab, and on elm foliage. It is a small reddish-brown louse which usually keeps its body covered with a white cottony secretion. It feeds by extracting sap from the roots and bark thru a piercing beak. On the roots this causes swellings to form and on the trunk and limbs slight depressions.

CONTROL.—In the nursery it helps to grow apple trees in fields which were formerly used for cultivated crops, and well isolated from old orchards, neglected apple trees, haws, crabs and elms. Also make sure that roots and scions are free from infestation when the grafts are made. Apple trees showing the presence of lice should not be disposed of until properly treated. Such trees may be fumigated with hydrocyanic acid gas as recommended for San Jose scale or the roots dipped in a solution containing one part of 40 per cent nicotine sulphate to 500 parts of water. One and two-year apples are less likely to be infested than older trees.

In the orchard make sure that the young trees when planted are free from lice. Use land that is not newly cleared but which has been cultivated for several years. If possible do not have old worthless apple trees, haws and elms too near the young orchard. For the first few years after setting out the

FIG. 2.—Root-louse of apple, showing typical root injury (After Stedman)

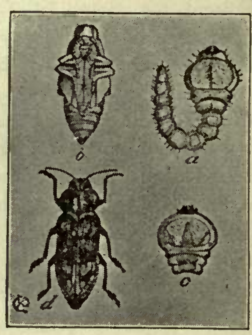

FIG. 4.—Flat-headed Apple-tree Borer; *a*, Borer; *b*, pupa; *d*, adult beetle. (From U. S. Dept. Agr.)

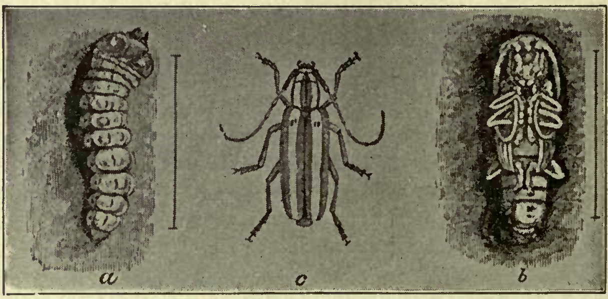

FIG. 3.—Round-headed Apple-tree Borer; *a*, Borer; *b*, pupa; *c*, adult beetle. (From U. S. Dept. Agr.)

young orchard scatter tobacco stems or tobacco dust about the base of the young trees and work it into the soil. On the large bearing trees this may also be done but it is especially important to young trees free from the louse.

Insect Pests of the Trunk and Limbs

In this group are included some of the most vital pests of apple; such as the borers and scale insects.

Round-headed Borer (*Saperda candida*).—This pest works just at the surface of the ground, throwing out of its tunnel sawdust-like cuttings. It is worse on neglected bearing trees in the orchard but also at times may appear on older apple trees in the nursery. It requires three years to complete its development from egg to adult. When full fed the fleshy, whitish grub or borer is an inch long and as large around as a pencil. The tunneling and girdling work weakens the tree and permits rot to set in.

Control.—In the nursery make sure that nearby old trees are not serving as breeding places causing infestation on the nursery trees. Also avoid carrying over scion trees or other unused trees until they become sources of infestation.

In the orchard cultivate about the trunks of the trees to keep down grass and other rubbish as it seems to attract or protect the pest. Also go over the trees in the fall and in the spring and carefully dig out, or destroy with a wire, borers where present. During the early summer months keep the base of the trunks painted with whitewash to which enough lime-sulphur solution is added to give a distinct odor. In Arkansas asphalt paint applied, at the temperature of about 115 degrees Centigrade, to trees four years old or older gave good results. Where possible it is cheaper and better to prevent infestation thru proper orchard management than to clean up the orchard once the trees are infested.

Flat-headed Borer (*Chrysobothris femorata*).—This pest is smaller than the round-headed borer and confines its work to the bark and growing layer of trunk and limbs. It is common on nursery trees and also in orchards. As a rule it works where mechanical injury, sunscald or canker is at work on a tree. The grub or borer is whitish in color and has the segments of the thorax expanded so as to appear to have an enlarged head which gives it its common name. It completes its life cycle in one year. It is not confined to the apple tree, which makes it all the more difficult to control.

Control.—During the early part of summer examine trees for signs of injury on trunk or larger limbs. If present carefully remove borers, disinfect wounds and paint over patches. As a precaution keep nursery and orchard as far from woods as possible and eliminate old worthless apple trees as well as haws and other trees from the vicinity of the orchard.

Shot-hole Borer (*Scolytus rugulosus*).—This small beetle and its tiny grub may attack all kinds of fruit trees and other trees. It is most important in the orchard but on weakened nursery trees it may also appear. The female beetle makes a tunnel between the bark and wood and lays eggs along either side of this. In time the small borers extend their work, often girdling limbs or the trunks of small trees, causing weakening or death of such trees. As a rule it is a weakened tree that is most likely to suffer injury.

CONTROL.—Since the pest thrives best in weak or dying trees or limbs, keep all orchard prunings removed from the orchard. In the nursery avoid the use of left-over trees for filling draws and the like alongside the growing stock. Remove and burn trees which are too seriously injured by the pest to be saved. In the orchard promptly prune out affected limbs and destroy them. The regular summer sprays with arsenate of lead and lime-sulphur for fruit insects will tend to repell this pest where spraying is thoroly done.

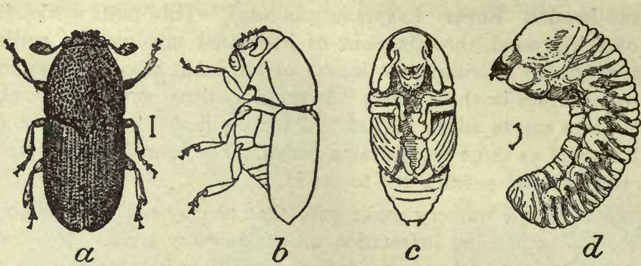

FIG. 5.—Shot-hole Borer; *a*, Adult; *b*, side view of same; *c*, pupa; *d*, borer; all enlarged. (From U. S. Dept. Agr.)

San Jose Scale (*Aspidiotus perniciosus*).—This imported scale insect is the most notorious one that attacks fruit trees. It came from the Orient some thirty years ago and has been in this state for about twenty-five years. It had much to do with the establishment of State and Federal Plant Inspection Services and hastened the day when regular orchard spraying was absolutely necessary. In thirty years it has destroyed thousands of orchards and has cost nurserymen millions of dollars.

It is a sap-sucking insect which secretes over its back a protecting scale or armor. The female gives birth to the young and in a day or two they insert their beak, begin to extract sap and to secrete the protecting armor. The females never move from the point where they begin to feed, tho later the males emerge as small two-winged insects. In from thirty to forty days the insect

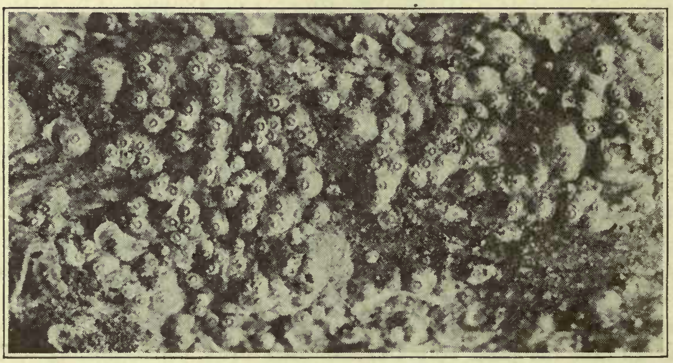

FIG. 6.—San Jose Scale; portion of peach limb showing scale incrusting it. Enlarged

matures, so there are a number of generations maturing between spring and fall. The pest passes the winter as a half-grown nymph in the so-called black stage.

CONTROL.—Since the pest may be spread readily in the young nymph stage from orchard to orchard or to nursery stock by birds or other means, the State Plant Inspection Service has done all in its power to eliminate the pest from orchards and other grounds in the vicinity of the nurseries. This clean up work has now largely removed the immediate danger to the regular nurseries. Under especially favorable seasons, however, the pest may multiply and spread more than usual, requiring special effort in the way of clean-up work. In the orchard one or two regular dormant sprays will so reduce it that it is then easily kept in control. No one hopes to absolutely exterminate it once it

FIG. 7.—San Jose Scale; blossom-end of apple enlarged slightly showing scale infestation

becomes well established. For the dormant spray use the regular concentrated lime sulphur solution which gives a Beaumeau reading on the hydrometer of 30° to 33°, at the rate of one gallon in eight gallons of water. Some prefer miscible oils and when used they should be mixed at the rate of one gallon of oil to twelve gallons of water. Some report good results with dry lime sulphur used at the rate of about 1 pound to 4 gallons of water. However, the writer's experience leads him to believe that in their present form the brands of dry lime sulphur will not control this pest as effectively as the better brands of lime sulphur solution.

A badly infested orchard should receive one application in November or December and a second one just as the buds swell in the spring. Where the infestation is light the spring application is sufficient. Select a warm day when there is little or no breeze. Use plenty of pressure and a nozzle throwing a reasonably fine spray, yet one which will penetrate into protected places. The spray solution kills by contact so each scale must be touched. Spray thoroughly therefore and be sure the tips of all twigs are thoroughly coated. Spray all the way thru the tree from all angles. Blotching of fruit is often the first signs of infestation the grower observes. However, other insects may cause blotches on fruit so this is not always a sign that the scale is present. In case of doubt send twigs and blotched fruit to the Agricultural Experiment Station for examination.

In the nursery the use of dormant sprays is not sufficient to insure against the possibility of spread of scale on nursery stock. Dormant sprays may con-

FIG. 8.—San Jose Scale. Spraying infested peach orchard, using small barrel outfit

trol the pest but it is humanly impossible to hit and kill every individual. For this reason inspection laws require the destruction of visibly infested trees and the fumigation or dipping of all other susceptible trees or shrubs before distributing them. For fumigation use an air-tight room and hydrocyanic acid gas. Subject the trees to the gas for from forty to sixty minutes. The gas is made by using one ounce of potassium cyanide 98% or sodium cyanide 130%, one ounce of commercial sulphuric acid, and two or three ounces of water for each one hundred cubic feet of space. If the stock is dipped, a miscible oil diluted with twelve parts of water has given best results. In spite of the most careful work of inspection and treating of nursery stock there is the chance that some scale may escape, resulting in infestation in the orchard where trees are planted. However, it should be remembered that in recent years most new infestations in orchards come from other infested orchards in the vicinity rather than on the young trees from the nursery.

While the scale has done much injury to fruit growing it is now possible to control it very effectively and in good orchard management it is no longer feared as a dangerous scourge. The above discussion of the pest on apple holds true for other tree fruits as well.

Other Scale Insects.—The oyster shell scale, the scurfy scale and the Forbes scale are also at times common on apple trees in the nursery and in the orchard. Neither of these, however, are likely to cause serious injury to bearing trees. In the nursery, on the other hand, they are undesirable and at times decidedly injurious. The scurfy scale has a light-colored flaky, armor, the oyster shell has a dark oyster-shell-shaped armor and the Forbes a circular armor with a shiny orange-colored center or exuvae.

CONTROL.—In the propagation of nursery stock select scions free from scales. Where nursery stock shows infestation do not use it in filling orders. To most fruit growers a scale is a scale and a nurseryman does not want the name of distributing scale infested stock. Dipping nursery stock in a miscible oil or fumigating with hydrocyanic acid gas will prevent the possibility of spread of these scales on the stock. In the orchard where these scales are troublesome a dormant spray as for the San Jose scale is helpful, especially for the Forbes scale and spring applications of contact sprays as for plant lice, just when the young scales are crawling is very effective in controlling the scurfy and oyster-shell scales, since they pass the winter in the egg stage.

Buffalo Tree-hopper (*Ceresa bubalus*).—In old neglected orchards the bark of small limbs and twigs is often found to be badly pitted and roughened. This is caused by this small insect. In the fall, by means of a small drill or ovipositor, the female places her eggs under the bark and this causes small scars on the bark. The injury is similar to the work of the Cicada, tho the punctures do not go beyond the bark. These eggs hatch in the spring and the young nymphs soon leave the twigs and feed on the sap of herbaceous plants, grass and the like about the orchard. The only damage done is due to the egg laying and in severe cases it may be considerable. Certain varieties suffer more than others.

In the nursery this injury is usually slight, tho it may be quite noticeable especially on scion trees in places where surrounding conditions are favorable for breeding.

CONTROL.—Where this pest is abundant clean culture in the orchard and surrounding fields will help to check the pest and its injury. Repeated mowing of grass and weeds in the orchard will help where cultivation is not advisable.

Periodical Cicada (*Tibicen septendecim*).—This peculiar insect, as is well known, reappears at definite intervals in the form of broods. One form reappears every thirteen years and the second every seventeen years. In Missouri several broods appear, tho only the two heavy 13-year broods are of special importance. One of these appeared in the spring of 1920 and will next appear in the spring of 1933. The second appeared last in the spring of 1911 and will next appear in the spring of 1924. These two broods are sufficiently heavy and widely distributed as to cause a certain amount of damage to the fruit-bearing twigs of apples and other fruits over most of the state. This is especially true

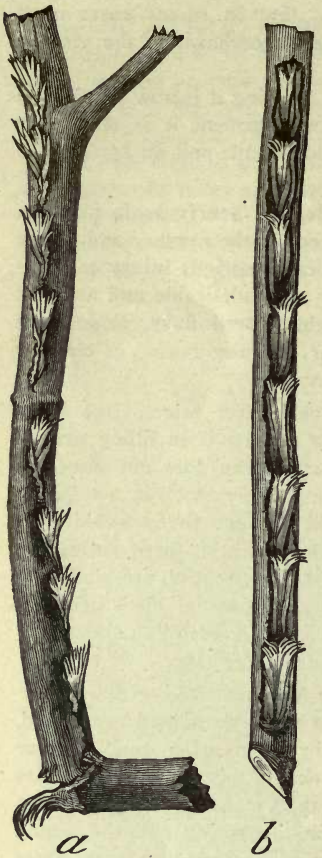

FIG. 9.—Periodical Cicada; limbs split by female Cicada for placing eggs (After Riley)

if orchards and nurseries are near timber land. In this case again the damage done is entirely due to injury caused by the splitting of the twigs for placing the eggs. No injury is done by the insect feeding on the trees.

Newly planted orchards and nursery stock suffer most. On bearing trees it simply serves as extra twig prunning and no serious damage results.

CONTROL.—There is no very effective treatment to check injury once the adult insects arrive in the orchard or nursery. Systematic driving will help to some extent. As a precaution one can determine in advance when the next brood will appear and if a young orchard is to be started select land that has been in cultivation for more than seventeen years if possible and select an orchard site as far as possible from timber. This will insure the least possible number of Cicadas in the orchard later when the pest appears.

Insect Pests of Apple Foliage

This includes a very large group of caterpillars, grasshoppers, plant lice, leafhoppers, plant bugs and other more or less destructive foliage pests. Where applications of sprays are recommended they are included in the regular spray schedule gi\e in connection with the control of the codling moth on page 22.

Canker Worms (*Alsophila pometaria and Paleacrita vernata*).—There are two species of canker worms, the fall and spring canker worms. The first appears as the adult in the fall and lays eggs while the latter appears in the spring. The female moth is wingless. The caterpillars are common dark-colored, span worms and do their destructive work just before, during and following apple blooming time. They often completely destroy the foliage and crop of fruit. There is one generation of the pest a year. The caterpillars when full fed leave the trees and pupate in the soil or rubbish. Here they remain until late fall or early spring, depending on the species.

CONTROL.—The pest is controlled effectively by spraying with an arsenical just before the blossoms open, or on isolated trees banding with tangle foot, or screen-wire cones is effective since the females are wingless and must climb up the trees to deposit eggs. Occasionally these caterpillars may do some damage to nursery stock and when they do apply arsenical sprays promptly.

Bagworms (*Thridopteryx ephermeraeformis*).—This peculiar cater-

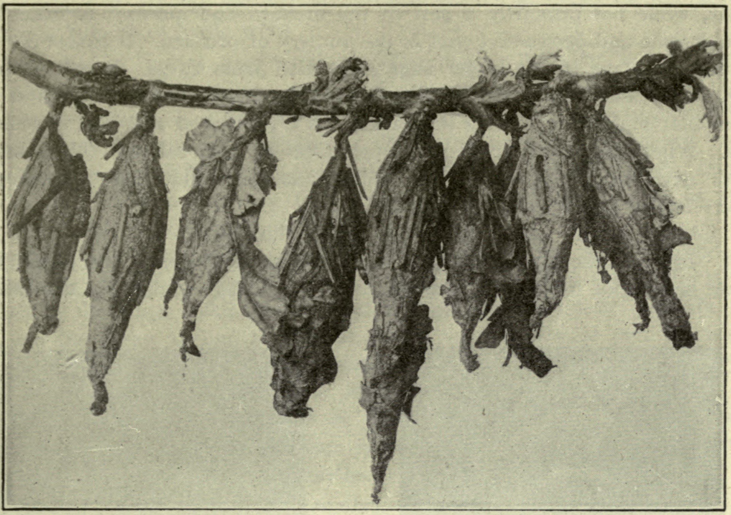

FIG. 10.—Bagworm; limb with a number of winter cases containing eggs

FIG. 11.—Bagworm; small apple tree showing work of young bagworms

pillar, while not primarily a pest of the orchard and nursery, is often a very troublesome and destructive pest in the nursery or orchard. It passes the winter in the egg stage in the larger bags suspended from twigs. In the spring the eggs hatch and they begin feeding soon after trees come into foliage. Each caterpillar makes for itself a bag or case as a protection and later it pupates in this. Where abundant it will strip apple trees of their foliage. The adult male moth develops wings, while the female remains within her protecting case where late in the fall she deposits her eggs.

CONTROL.—The calyx spray for the codling moth will also control this pest. In the nursery spray early in the spring so as to poison the young worms. Hand picking of the bags in the fall after the foliage is off will also help con-

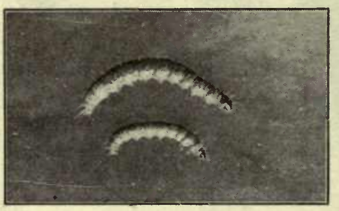

FIG. 12.—Apple-tree Leaf-roller; two larvae slightly enlarged (After Stedman)

FIG. 13.—Apple-tree Leaf-roller; pupa slightly enlarged (After Stedman)

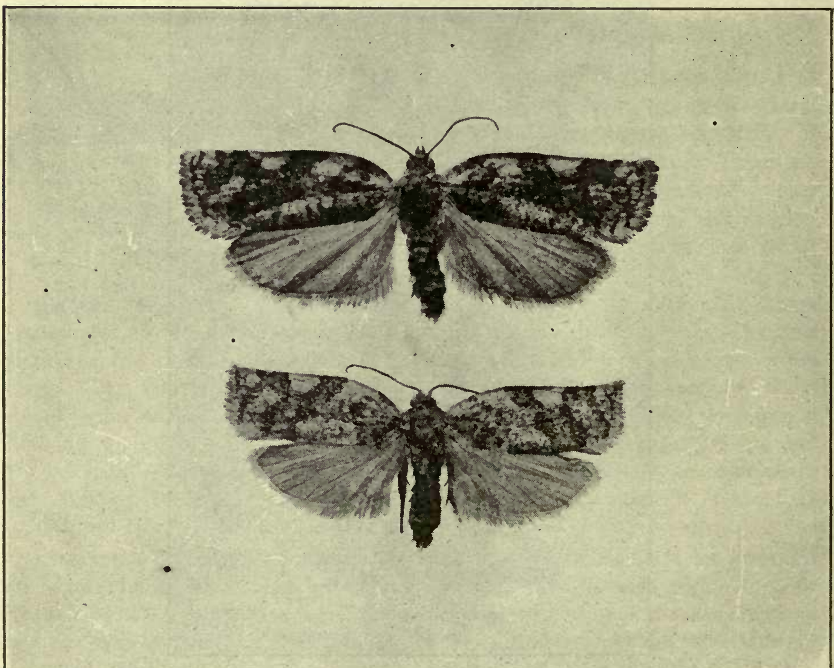

FIG. 14.—Apple-tree Leaf-roller; adults much enlarged (After Stedman)

trol the pest. It attacks various evergreens, shades and ornamental shrubs worse, as a rule, than apple trees.

Leaf-roller (*Archips argyrospila*).—This small caterpillar is often very destructive to foliage of nursery trees and occasionally to bearing apple trees. It may have three or four broods a year in this state and when abundant the small yellowish millers are conspicuous about the nursery or orchard trees. The small active caterpillars roll or fold the leaves on which they feed. It may also feed to some extent on the fruit, especially around the blossom or stem end or where two fruits touch.

CONTROL.—In the nursery arsenical sprays applied just as the broods of young worms begin their work has proven entirely effective in one of the larger nurseries in the state. The development of the pest should be carefuly followed and the spray applied before the young worms fold or curl the leaves too much. In the orchard the regular summer applications of poison sprays, will control any ordinary outbreak of the pest. The pest passes the winter in the egg stage. The eggs are deposited on limbs or twigs in small circular light patches. Some have used oil emulsion sprays to destroy the winter eggs with fair results while others find them ineffective.

Leaf-crumpler (*Mineola indigenella*).—The leaf-crumpler is one of the most common foliage feeding caterpillars on young trees in the orchard or nursery. The caterpillar is a small reddish or brownish colored caterpillar which prepares, and lives within, a slender, coiled case. The case is usually attached to a twig and has one or more leaves attached to it. It passes the winter as a half grown caterpillar and transforms to the adult early the next summer. It feeds on the foliage of other trees, fruits and haws.

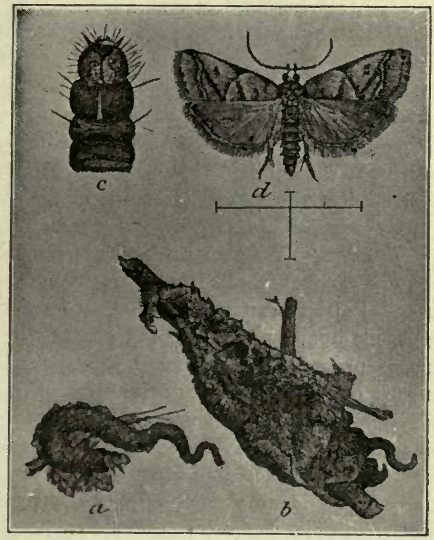

FIG. 15.—Leaf-crumpler: *a*, Tube with larva head protruding; *b*, cluster of tubes; *c*, head of larva, enlarged; *d*, moth, enlarged

CONTROL.—It is most abundant on small trees and in the fall or winter when the leaves are off the trees it is an easy matter to see and remove by hand the winter cases containing the small caterpillars. An arsenical spray applied soon after the foliage appears in the spring is also effective. In the nursery this is the most practical remedy. In the bearing orchard the regular summer arsenical sprays control this as well as other common foliage-feeding caterpillars.

Leaf-miners (*Spp.*).—There are a number of small caterpillars which live and develop within the cellular structure of the leaf. The serpentine, blotch, trumpet and tentiform leaf-miners are the most common ones found in the foliage of apple trees. Besides these the pistal and cigar case-bearers and the ribbed cocoon makers are also common some seasons. In this state these small caterpillars do not often cause serious damage. In 1911 and 1912 the unspotted tentiform leaf-miner was very abundant and injured foliage seriously tho fortunately it becomes most abundant late in the fall after the crop and most of the growth has been matured. In the nursery where apple trees are dug and sold as one, two or three-year trees, these caterpillars do no serious damage. In the bearing orchard the regular arsenical sprays for fruit pests help some and natural parasites also help to prevent serious damage. As a rule, therefore, special treatments are unnecessary.

Other Foliage Caterpillars.—Besides the foregoing foliage caterpillars there are a number of very common species in the nursery and orchard which some seasons may attract much attention but which as a rule do not require special treatment. The yellow-necked and red-humped apple worms, the fall web-worm, apple tent-caterpillar and white-marked tussock moth are the more common caterpillars in this group. Every year we have some of these present but the amount of foliage they consume is usually not sufficient to warrant spraying or applying other treatments.

CONTROL.—In the bearing orchard the regular arsenical sprays are entirely effective. In the nursery or when injurious on young orchard trees the worms may be collected by hand or shaken off and crushed under foot or an application of an arsenical spray may be made just as the worms begin to attack the foliage.

Grasshoppers (*Spp.*).—During seasons of heavy grasshopper infestation, orchard and nursery trees are sure to suffer where the grasshoppers are permitted to migrate from adjoining pastures, meadows or other crops. There are three common species of grasshoppers which do this damage, the red-legged, differential and two-lived. Where injury occurs it is usually soon after hay harvest. The foliage is often completely devoured and serious injury may result where the hungry grasshoppers attempt to appease their appetites further by gnawing the bark from the twigs and even the trunks of small trees.

CONTROL.—Where grasshoppers are abundant on crops near the orchard or nursery one should take precautions early in the summer to prevent trouble later. Poison bran bait sown broadcast in infested meadows and other crops when the hoppers are yet small will rid the community of the pest. Poison bran bait is prepared by mixing dry 50 pounds of bran and two pounds of white arsenic or Paris Green and moistening this with about 8 gallons of water with which are mixed 4 quarts of cheap sorghum and the juice and chopped up rinds of six lemons. Sow this at daybreak so the hoppers will get it for breakfast while yet moist and attractive. Where this precaution is not taken and the hoppers are feeding on the foliage spray the trees heavily with an arsenate of lead solution.

Plant Lice (*Spp.*).—The foliage of apple trees may be seriously injured by two common green lice and one rosy louse. The injury is usually heaviest early, from the time the buds open until the fruit is well set. During the winter the lice eggs may be found attached to limbs and twigs, especially in the leaf scars and other protected nooks. The lice feed by extracting sap from leaves, blossoms and setting fruit. This causes a curling of the leaves and a knotting and dwarfing of the fruit. In severe cases the crop of foliage and fruit may be practically all destroyed. Since the lice are sap feeders, arsenical sprays have no effect on them since it is impossible for them to take poison into their stomachs.

CONTROL.—In the bearing orchard where the plant lice are injurious spray

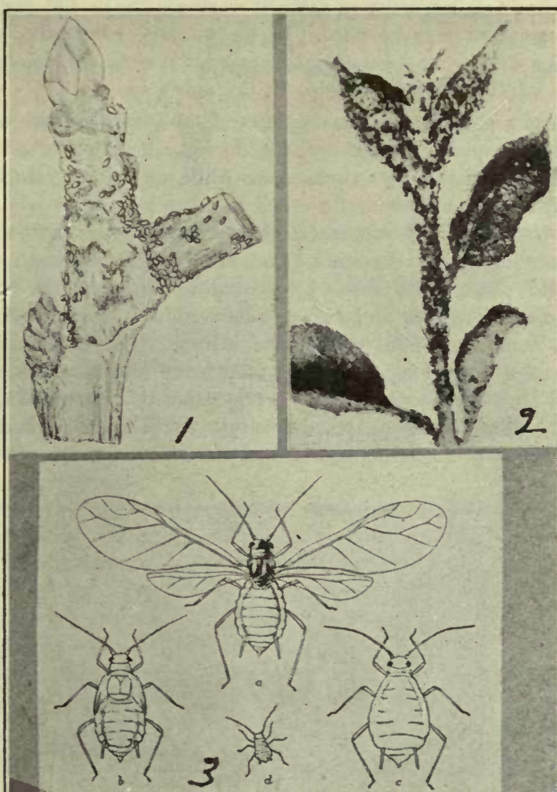

FIG. 16.—Plant lice: 1, Winter eggs on twig; 2, lice on tip of apple twig; 3, development of louse, enlarged

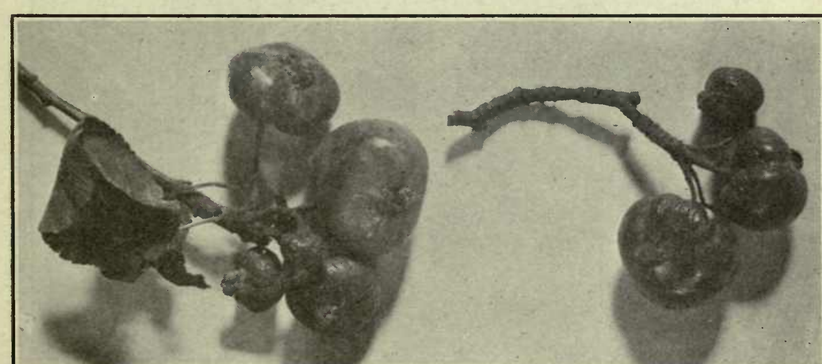

FIG. 17.—Plant lice; apples dwarfed due to plant louse injury. (After Talbert)

with a nicotine solution promptly. It may be combined with the regular cluster or calyx sprays. Commercial nicotine sulphate containing 40% nicotine used at the rate of one pint to one hundred gallons of water or combined with one hundred gallons of regular spray mixture is very effective. On young orchard trees the same solution may be used. In the nursery where the buds, leaves and growing tips are being injured spray promptly with the nicotine solution or where practical dip the infested tips in the solution.

Leaf-hoppers.—Apple trees in the nursery and orchard are attacked by two common leaf-hoppers. In the orchard the rose leaf-hopper and the apple leaf-hopper are often both very troublesome while on nursery stock the latter is especially injurious.

Since 1910 the apple leaf-hopper (*Empoasca mali*) has repeatedly attracted attention in the nurseries of the state. In 1911 and 1912 it was especially injurious. Like the plant lice it feeds by extracting sap from the young leaves both as the immature nymph and as the adult. This causes a curling of the leaves attacked somewhat like plant louse injury. The characteristic white speckled appearance on the upper surface of injured leaves on bearing trees is less pronounced on the young vigorous nursery trees tho in severe cases it may show up some. This species passes the winter in the adult winged stage in dry grass and other protection about the orchard or nursery. In the spring

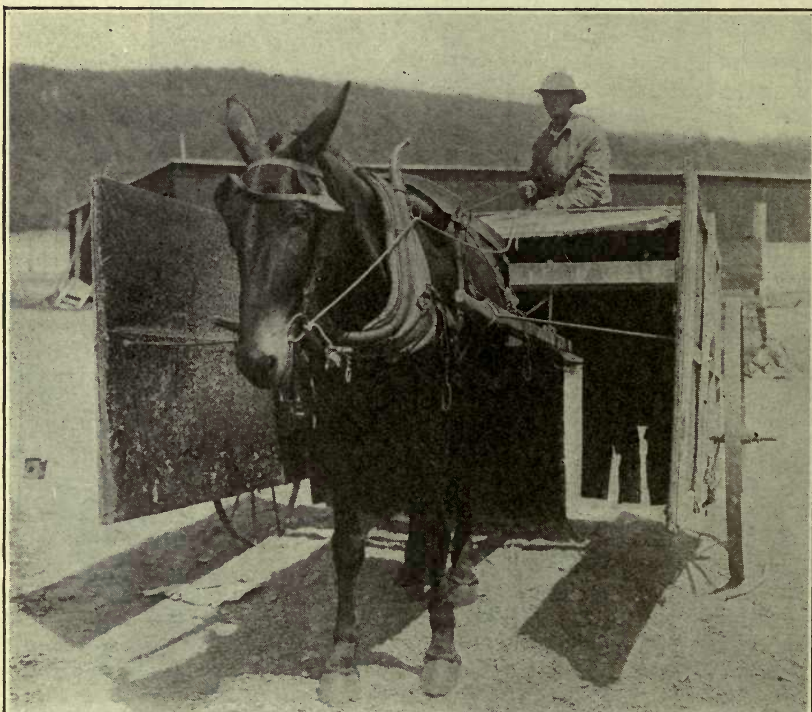

FIG. 18.—Apple Leaf-hopper; trap used for running over rows of nursery trees to catch adult leaf-hoppers

they fly to the apple tree to feed and deposit eggs. During the summer in Missouri this species develops three or four broods usually increasing in abundance towards fall. Besides apple it also breeds on and injures the foliage and young growth of Norway and hard Maples as well as certain vegetables.

In Missouri the rose leaf-hopper (*Empea rosea*) seldom attracts attention in the nursery but is very abundant toward the close of the season on bearing apple trees. This fall (1920) the pest was so abundant in orchards in central Missouri that much of the apple foliage was badly injured and the air was often so full of the adult hoppers that they annoyed one working in or passing thru the orchard.

This species is creamy white to light yellow in color with a tinge of orange on the face of the male. It passes the winter in the egg stage under the bark of apple and rose. It is also multiple brooded and is most abundant in late fall.

CONTROL.—In the nursery, leaf-hoppers may be controlled with a fair degree of success by using a large trap including sticky shields for catching the adults as well as the older nymphs. In this state spraying with nicotine solution or oil emulsions have not proven to be practical on any large scale. One thorough application of a contact spray to control the first brood of nymphs in the spring will reduce later injury but a trap with sticky shields can be run more economically and effectively and where used by nurserymen it has replaced the use of sprays.

In the orchard spraying is usually unnecessary and at best not very effective. Thorough destruction of the overwintering adults of the apple leaf-hopper where they collect in grass and other protection is a more practical check on this species. This is not effective against the rose leaf-hopper, however, since it passes the winter as the egg under the bark. Fortunately the rose leaf-hopper becomes alarmingly abundant only toward fall when its injury to foliage is less important.

Tarnished Plant-bug (*Lygus pratensis*).—This pest is one of the most important pests of budded nursery stock. It does injury in the orchard, too, but its most prominent injury is in the nursery. It is a world-wide pest of various crops and plants and is a most difficult pest to completely control.

In the nursery the injury is done early in the spring when the overwintering adults suck sap from and blight the young buds and growth. Peaches are especially subject to their attack tho cherry, pear and other stock also suffer. The insect is multiple brooded and lives thru the winter in rubbish as the adult winged bug. Typical "stop-back," "bush-head" and other similar injury to nursery stock is largely the work of this pest. Often entire blocks of nursery stock are so attacked that few or no trees of marketable grade may be saved. Hundreds of acres of nursery stock are damaged every year by this pest.

CONTROL.—This pest breeds primarily on weeds in or near the nursery and passes the winter in rubbish near the nursery. The first treatment to consider, therefore, is clean culture in the nursery and make sure that draws, fence rows and neighboring fields do not serve as breeding places for this pest. Then make sure that all harboring places are burned over or plowed under during the late fall or winter. This will prevent much of the danger.

When the pest begins its destructive work on the trees in the spring systematic driving or heavy rains or other means of driving the pest from the trees will check injury. If the injury does not occur until growth has well

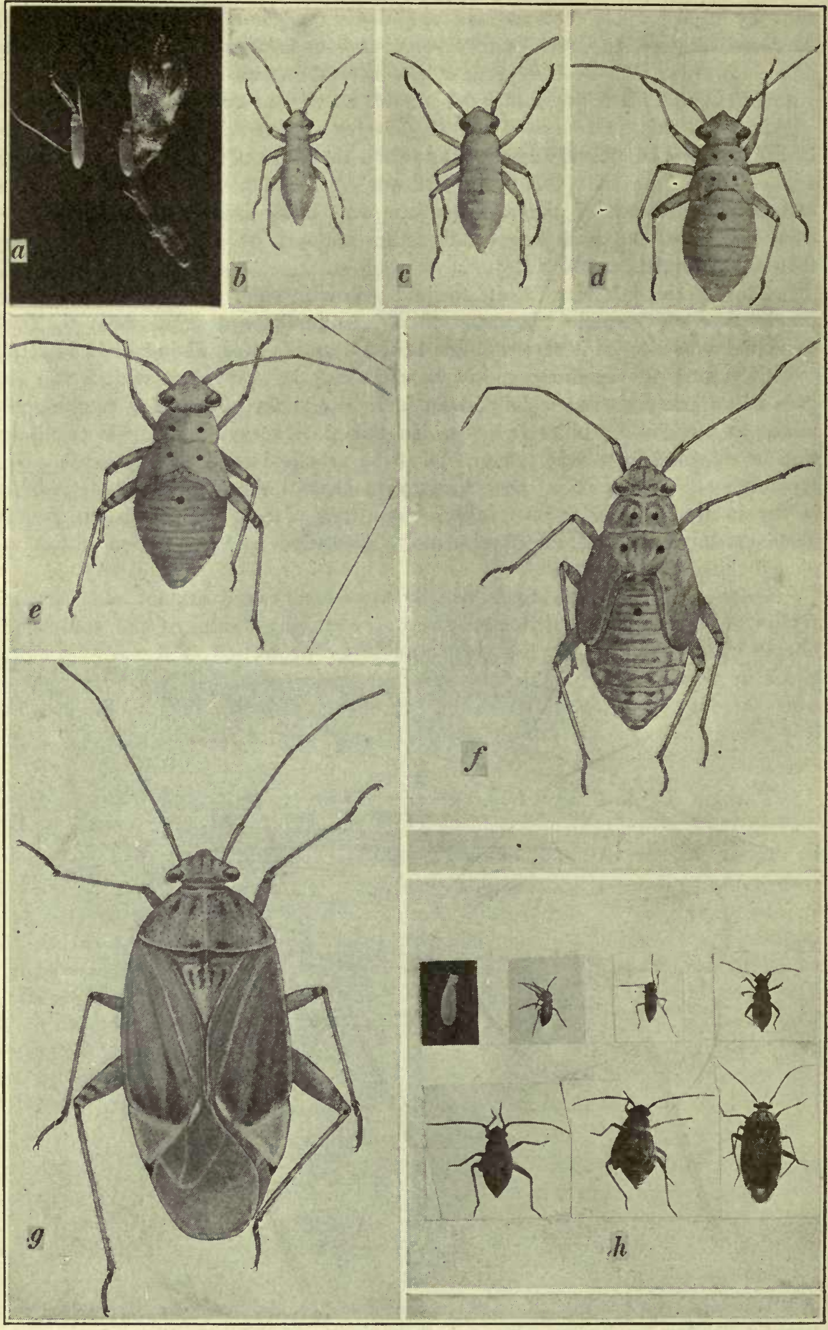

FIG. 21.—Tarnished Plant-bug; life cycle of pest showing egg, five nymph and adult stages. Enlarged

started one can reshape injured trees by pruning. However, young buds or budded stock may be killed outright and the trees lost. In the orchard the

FIG. 22.—Tarnished Plant-bug; *a*, injured peach trees in nursery rows; *b*, close view of tree showing bush-head or typical injury done by the pest

pest seldom requires attention but weeds and winter rubbish should always be destroyed so as to prevent the pest from ever becoming abundant.

Apple Fruit Insects

In Missouri the apple worm or codling moth and the plum curculio are the two most important insects attacking the fruit. The San Jose scale in scale infested orchards also settles on the fruit seriously damaging it. Of the less important fruit pests, we have plant lice, lesser apple worm, apple curculio, apple maggot and a number of caterpillars which may feed on the surface of the fruit thruout the season. However, the spraying schedule, directed especially at the codling moth and plum curculio, is so arranged as to protect the fruit also from those pests of lesser importance.

Codling Moth (*Carpocapsa pomonella*).—This small pest in the pink-worm feeding stage is known to all who eat apples. It has been a pest of apples from the early days and in neglected orchards it ruins most of the fruit. Its development and injury to fruit is influenced both by climatic condition and its geographical location. In Missouri the pest develops normally two full broods and at times three, or in the Ozark section even a partial fourth brood, some claim. However, the control measures in the past have been directed primarily at the spring and summer broods.

MOTH.—The adult moth expands about three-fourths an inch and is not often observed about the trees. When at rest its wings are folded over the back and the irregular gray and brown bands on the fore wings give it a grayish-brown appearance. It becomes active about dark and deposits its eggs mostly on the leaves surrounding fruit clusters, tho occasionally on the side of fruits.

EGG.—The egg is a pearly-white, scale-like object which can be detected only after careful search. The eggs hatch in about a week, depending upon the temperature.

LARVA.—The young larva, like the egg is small and difficult to see with the unaided eye. If hatched near fruit the larva in time may reach the fruit and gain entrance. In time it makes its way to the core and later feeds on the seeds and surrounding part of the apple. The larva at first is light but usually takes on a more or less distinct pink color. It feeds for about one month and when full fed is about three fourths an inch in length. On maturing the larva leaves the fruit, spins a cocoon in some protected place, such as under the bark of the tree and in time pupates.

PUPA.—The pupa is a small brownish object very similar to other related species. It is about one-half an inch long and is found inside a small but rather firm cocoon. In the summer it usually remains in the pupa stage for from about one week to ten days and then emerges as the adult.

The insect passes the winter in the larval stage in the cocoon protected under the bark of the tree or about apple boxes, pens or where apples were stored for a time after picking. The larvae pupate just before apples begin to bloom and the adults emerge soon after the blossoms drop. Eggs are soon deposited and the first young larvae begin to hatch about two weeks after the blossons are all off.

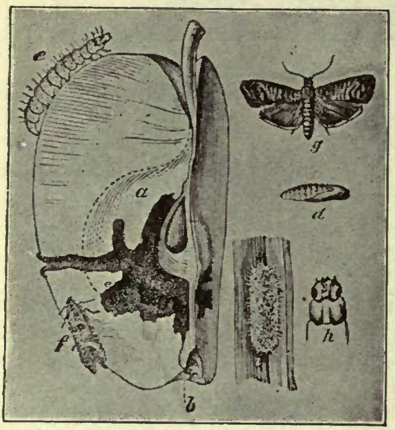

FIG. 23.—Codling moth; stages of development and injury to apple (After Riley)

Those worms which gain access to fruit become fullfed in about a month, when they leave the fruit, spin their cocoon and later emerge as the summer brood moths. In central Missouri these usually appear on wing during the first ten days of July. However, they may be hastened or retarded in thier development by temperature so each fruit grower should determine the date of emergence of the summer brood of moths in his own orchard. This he can do either by collecting a few wormy apples in June, and putting them in a tight box or other container where later the emerging of the moths can be observed or by putting rag bands on a few trees under which the worms will collect to pupate, and where the first emerging of adults can easily be determined. It is important to know when the July or summer brood of moths emerge so as to properly time the July application of spray.

Where a third brood develops the moths emerge late in August and the small worms may be found in the fruit at picking time in the fall. In the southern part of the state spring opens earlier and the pest has a longer breeding season. This permits the pest to develop more broods and to do more damage to the fruit.

During the present spring, summer and fall conditions in Missouri have

FIG. 24.—Codling moth. Apples at proper stage for applying calyx spray. (After Talbert)

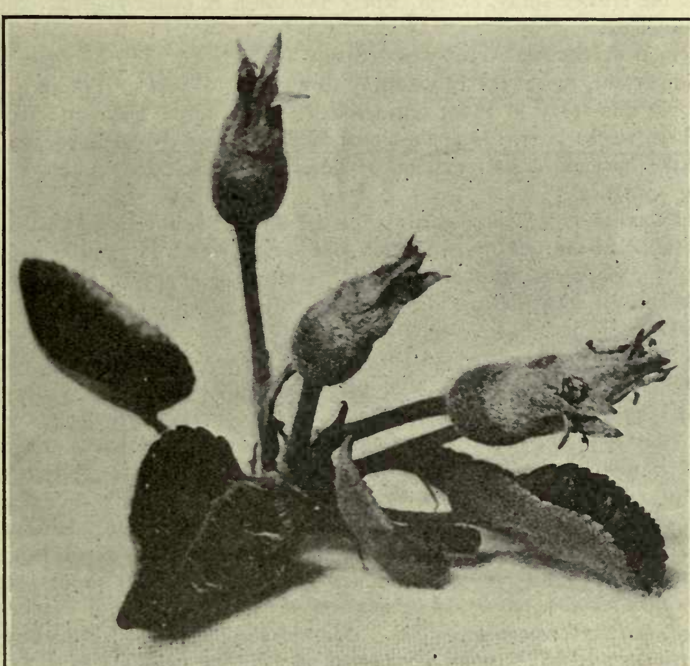

FIG. 25.—Codling moth; Apples too far advanced for calyx spray. (After Talbert)

been somewhat abnormal and an unusually large number of worms appeared late and the fall injury has been unusually severe, even in some sprayed orchards.

Control.—In the control of this pest we depend primarily on spraying. Some relief comes from the proper disposal of wormy fruit and the attraction of insectiverous birds to the orchard, but the real relief comes from a systematic use of insecticides. The spray schedule for apple is arranged first of all to reach the codling moth, but the different applications are so timed and so combined as to reach all the important fruit and foliage insects as well as those fungi which also must be controlled. This schedule may include all or part of the following applications, depending on conditions in the orchard.

Dormant Spray.—This spray is needed only when San Jose scale is present. It may be either a lime-sulphur solution or an oil emulsion as outlined under the control of San Jose scale.

Cluster Spray.—This is given just before the blossoms open but after the cluster buds separate. If plant lice, canker worms and apple scab are also to be controlled, the spray solution should include one and a half gallons lime sulphur solution, one pound powdered arsenate of lead or two pounds of paste arsenate of lead and one-half pint of 40% nicotine sulphate to fifty gallons of water.

Calyx Spray.—This is given just after the most of the blossoms are off and before the calyx ends of the young fruits close. It includes the same materials as the cluster spray, except, where the louse is under control, omit the nicotine sulphate.

Curculio or Second Apple-worm Spray.—Where curculio or apple blotch are not important, repeat the calyx spray in about two weeks. Where curculio is bad apply this spray in about one week after the calyx spray and repeat it two or three weeks later. If apple blotch is present use 3-4-50 Bordeaux mixture for the one and a half gallons of lime sulphur solution in this and the following spray.

Local conditions will necessarily vary the time of application and the mixture for this and the one or two additional sprays which it may be necessary to apply in close succession. It is well for all fruit growers to keep this in mind and consult with the spray specialists of the College of Agriculture when conditions are abnormal.

July Spray.—This is applied just before the apple worms of the second or summer brood hatch and begin to enter the fruit. It usually includes one and a half gallons of lime sulphur solution and one pound powder or two pounds paste arsenate of lead to fifty gallons of water. If blotch is present the Bordeaux is used as the fungicide in place of the lime sulphur solution.

Where additional broods of the codling moth or where summer and fall fruit diseases are destructive it may be necessary to put on additional applications and the College of Agriculture should be consulted regarding these.

Plum Curculio (*Conotrachelus nenuphar*).—This small snout beetle is abundant thruout the state. It breeds primarily in plums and peaches but often does serious damage to apples. It attacks apples both for feeding and for ovipositing, but only a small percentage of the eggs deposited in apples succeed in maturing. The crescent gashes made by the adult beetle usually heal over later tho often they serve as entrance places for the small apple worms and for various fungi.

The adult is about the size of a garden pea and is blotched with brown, gray and black. It has a short, stout snout and rather distinct humps or bumps on the back. It passes the winter in the adult stage in rubbish and other protection. In the spring about two weeks after apple blossoms fall or when wild-goose plums are the size of the tip of ones small finger, the adult appears on the fruit, cutting crescent gashes for egg laying or circular pits for feeding. When these eggs hatch especially in stone fruits the yellowish white footless grub bores down into the fruit to feed. It is the typical slightly curved worm found in plums which ripen prematurely and in wormy peaches. The fullfed worms in central Missouri leave the fruit in about three weeks after the eggs are laid. These enter the soil to pupate, and around the middle to the last of July they again emerge as the adults. These may feed on fruit until Fall and are usually responsible for most of the plum cruculio injury to apples. There is normally one brood a year, tho often in unusual years as in 1920 larvae may be found feeding in peaches as late as September.

FIG. 26.—Plum Curculio; adult curculio, much enlarged. (After Stedman)

CONTROL.—This pest can be controlled in part by poison sprays, and the spray applied one week after the calyx spray is so timed as to reach the adults while making the egg and feeding punctures soon after the fruit sets. It should be remembered, however, that sprays are less effective for this pest than

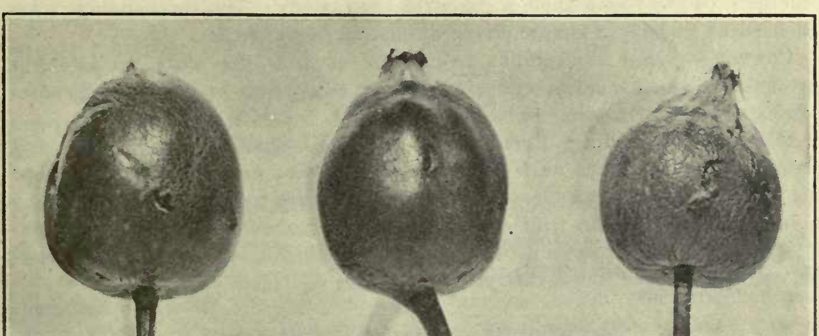

FIG. 27.—Plum Curculio; apple showing typical crescent gashes made by plum curculio for placing eggs. (After Talbert)

for the apple worm. For this reason the sprays should be supplemented by the practice of clean culture to destroy the overwintering adults, the prompt disposal of wind-fall fruit with the enclosed worms and, where practical, shallow cultivation under stone fruit trees during July to destroy the soft, helpless resting stage of the pest. On small trees it is possible to jar the adults onto sheets, when they begin to attack the fruit, and thereby destroy them. Since this species breeds largely in stone fruits, injury to apples can be greatly reduced if peaches, plums and cherries are not planted in or near the apple orchard.

San Jose Scale.—As previously mentioned, the scale settles on the fruit as well as on the foliage and the timber of the tree. The crop on scaly trees may be practically ruined. Its market value is reduced and the quality of the fruit is also injured. If remedial measures previously discussed are applied to protect the tree the fruit will also be protected. The dormant spray is necessary as the summer sprays are too weak to control the pest to any extent.

Plant Lice (*Spp.*).—When the plant lice are abundant on buds, foliage and twigs at blooming time and soon thereafter the young fruit is also sure to suffer. The lice sucking sap from the young fruits cause a dwarfing or complete check in its normal growth. This reduces the yield as well as quality. If necessary sprays to protect foliage and growth are applied, the fruit also will be protected.

Lesser Apple Worm (*Enormonia prunivora*).—This small caterpillar somewhat resembles the real apple worm, tho it is smaller and usually of a deeper pink color. It feeds just under the skin of the fruit producing a mined-like effect. Its life cycle and feeding habits are quite similar to those of the apple worm and the regular spray applications for the latter will control it as well. For the past several years in Missouri this pest has been of comparatively little importance.

Apple Curculio (*Anthonomus quadrigibbus*).—This snout beetle, may become very destructive to apples, tho as a rule it is the work of the plum curculio that causes most damage in Missouri. Its life cycle is similar to that of the plum curculio except that it seems to enter hibernation quarters earlier and thereby does less injury to the fruit by feeding in the summer and fall. It makes a small circular opening in the surface of the fruit and hollows out below in the flesh of the young apple a cylindrical egg cavity. The surrounding tissue then hardens, causing a characteristic deformity of the fruit.

CONTROL.—Spray applications help some as with the plum curculio but they must be supplemented with clean orchard practices and prompt disposal of infested windfall apples early in the season.

Other Fruit-feeding Caterpillars (*Spp.*).—Some seasons green and ripening apples are more or less injured by different caterpillars. The green fruit worms and the apple leaf-roller are often quite troublesome. They may eat rounded holes in the fruit or irregular gashes about the stem or blossom end. Where a regular system of summer sprays, including an arsenical, is applied year after year, these caterpillars do little damage.

INSECT PESTS OF THE PEAR

In Missouri the pear is attacked by only a few of the worst pear pests. San Jose scale, codling moth, curculio, and blight are most commonly complained of on pear. Pear slug may do considerable damage but pear psylla and blister mite are seldom of serious consequences. The discussions on apple insects covers also pear injury and a separate discussion is unnecessary here.

In the nursery do not grow pear trees near old blighted trees and do not permit wild haws to stand in or near the pear blocks. Pear trees should be carefully gone over so that all trees which may show the least signs of blight are detected and thrown out.

Pear Slug (*Eriocampoides limacina*).—This pest attacks the foliage of pear and cherry often very badly. It is a small greenish, slimy worm similar to the rose slug and related species. Often a dozen may feed on one leaf, consuming the surface layer, which causes the leaf to dry up. The pest develops two broods a year, the adults of the first appearing in June while the adults of the second appear in August. The first brood is most destructive.

The pest attacks the foliage of trees both in the nursery and in the orchard. As a rule cherry is attacked more severely than pear.

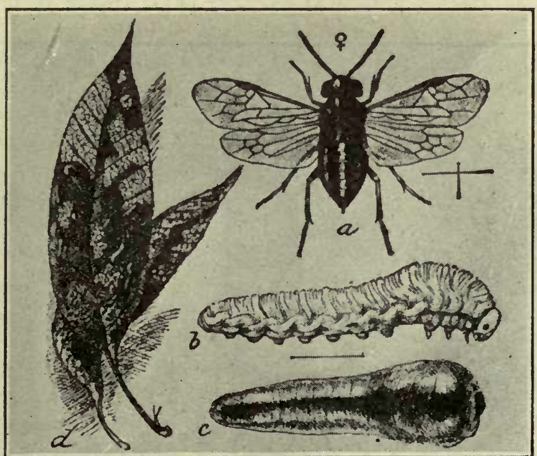

FIG. 28.—Pear slug: *a*, Adult female sawfly; *b*, larva enlarged; *c*, back view of same; *d*, injured leaves with larvae, natural size. (After Marlatt)

CONTROL.—Where the regular summer sprays are applied to bearing trees the pest will be controlled. On nursery stock the pest can be controlled by dusting or spraying with an arsenical.

INSECT PESTS OF THE PEACH

The peach in the nursery and orchard is not subject to as many pests as is the apple, however, there are a number of important peach pests. Of these the peach-tree borer, the San Jose scale, the plum curculio, the tarnished plant-bug, the peach twig-borer, the shot-hole borer, and black peach aphis are usually the most important.

Peach-tree Borer (*Sanninoidea exitiosa*).—This is a caterpillar borer which, while especially important in the orchard, may at times attack older peach stock in the nursery. Its presence is usually readily recognized by the appearance of peach gum about the base of the tree. . The borer varies from a very tiny whitish caterpillar to one an inch long and of a yellowish-white color. It works between the bark and the wood from a few inches above the ground usually to a few inches below ground. The adult moth resembles a wasp in appearance and action. The male has transparent wings and the body steel-blue in color with yellow on the tip while the female is larger, wings more completely covered with blue scales and the body is steel-blue with a distinct orange band.

The pest passes the winter in the larval stage. In some cases the larva may be very small while in other cases it may be almost mature. In the peach belt of the Ozarks the moths begin emerging from the more advanced over-wintering larvae around the last of May but the heavy emergence and egg laying usually comes between the middle of June and the first of August.

Control.—The peach-tree borer is no exception to the rule that fruit tree borers are difficult and expensive to control. Worming by hand and the use

Fig. 29.—Peach tree Borer: Crowns of peach trees showing borers and injury. (After Chandler)

of repelling or protecting paints should always be supplemented by clean culture and the removal of old worthless, borer-breeding peach trees and snags. In the nursery do not hold over any old trees as breeding places for borers and keep the young peach blocks as far as possible from old peach or plum trees. Do not sell peach trees which show signs of being infested with borers, unless they are fumigated.

Badly infested trees should be wormed in the fall and again late in May before the moths begin to emerge. Dig away the dirt and gum and with a knife blade locate and destroy the borers without injuring the tree more than necessary. After the borers are removed in late May paint or spray the trunk and exposed roots with one part of lime-sulphur solution to ten parts of white wash solution. If applied with a sprayer it should be made thinner than if painted on. When dry, mound up about the trees. One pound of arsenate of lead may be added to every ten gallons of the paint or wash.

San Jcse Scale.—This pest and its control on peach is largely a duplication of its work and control on apple. Peach nursery stock infested with or exposed to the scale should be treated the same as apple stock.

Plum Curculio.—The life cycle and habits of this pest have already been discussed under apple insects. The pest breeds most abundantly in peaches and plums and special effort should be made to prevent it from developing in these fruits. Clean culture, destruction of wormy windfalls, jarring where practical and shallow cultivation in July should be supplemented with the use of arsenical sprays to poison the adults as suggested on apple.. The peach foliage is more easily burned than that of apple so greater care must be taken with mixing and applying sprays to peaches. The fuzzy nature of the peach enables it to hold the poison better than either apple or plum. Where curculio injures peach the spray application given when most of the shucks or collars are off the young fruit and the application given one week to ten days later are the most effective applications. They should include about one pound powdered or two pounds paste arsenate of lead to fifty gallons of the 8-8-50 self-boiled lime-sulphur solution. Do not use the ordinary commercial lime sulphur for spraying peaches when in leaf as it injures foliage. As a dormant spray, however, it is all right for controlling San Jose scale.

Tarnished Plant-bug.—This pest has already been discussed more especially as a pest of nursery stock. Peach nursery stock suffers more than other

FIG. 30.—Peach-twig Borer; showing larva, pupa and injured peach bud. (After Marlatt)

FIG. 31.—Black Peach Aphis; peach tree showing lice on roots (After Smith)

types tho pear, cherry, and apple may also suffer from the pest. In the bearing orchard peach does not suffer much injury.

Peach Twig-borer (*Anarsia lineatella*).—This small caterpillar is often very injurious to buds and new growth on both nursery and orchard trees. Bearing trees are usually more seriously injured than younger trees. In the summer and fall it is also often quite troublesome, working into the fruit around the stem end or where fruit cracks. Late peaches suffer most.

It passes the winter as a young larva in a small chamber made in the bark usually at the fork of two small twigs. In the spring these larvae bore into buds and tips of new growth often killing several buds before maturing. These pupate in curled leaves or other protection and the small, dark-gray moth soon emerges to lay eggs for the next generations. . The later generations work more in the fruit and less in the twigs.

Control.—This pest is usually most abundant on neglected trees tho well kept peach orchards may become seriously injured. The best means of reaching the pest is to apply the lime sulphur spray in the spring just as the young larvae are leaving their winter quarters. The spray may be applied, after the buds begin to open but before the blossoms are open, with effective results on the borer and yet not seriously injure the peach foliage.

Shot-hole Borer.—This species has been discussed under the apple insects and the same treatments recommended there will control the pest on peach trees.

Black Peach Aphis (*Aphis persicae-niger*).—This louse has been reported on peach in Missouri but thus far no serious injury has occurred. It works on the roots and in the summer some may come up on the leaves and twigs. It resembles other plant lice in feeding habits by extracting sap. It is a very dark-colored louse.

Control.—If nursery stock becomes infested it should be thoroughly fumigated before being disposed of. In the orchard nicotine sulphate sprays are effective where the louse appears above ground and tobacco dust is suggested for the root form where injurious. Thus far this species has not done any appreciable injury in the state.

The most up-to-date peach orchards of the state usually receive clean culture which materially reduces the favorable conditions for various insects. It is usually the neglected orchard where the above insects are most abundant and injurious.

INSECT PESTS OF PLUM AND CHERRY

Plums and cherries are subject to about the same insects as peaches. The San Jose scale attacks certain types of plum and sweet cherries very badly. The plum curculio attacks the fruit of plums and cherries often completely destroying the crop. The peach-tree borer may also do some damage on both plum and cherry. The peach terrapin scale also attacks plum. The plum louse and the cherry louse are also injurious some seasons. The cherry scale often becomes injurious.. The cherry maggot is seldom injurious to cherries in the state as is also true of the apple maggot or railroad worm in apples. Where plum and cherry are attacked by pests discussed under apple and peach insects simply refer to recommendations given under those fruits.

Rusty Brown Plum Louse (*Aphis setoriae*).—This dark-brown louse is usually most injurious early in the season. It also attacks peach. It attacks the leaves and young growth. Where abundant one application of the regular nicotine spray will control the pest. It is not often that sprays are necessary on nursery stock.

Cherry Louse (*Myzus cerasi*).—This pest is most severe on sweet cherry trees in the nursery. Injury on bearing trees is usually slight. Prompt applications of the nicotine spray or the dipping of the tips in the solution will give relief.

Cherry Scale (*Aspidiotus forbesi*).—This scale is found commonly on both bearing cherry and apple in this state. Occasionally it seriously encrusts cherry trees. It may also appear on young trees in the nursery, especially apples where the scions are taken from trees showing infestation. Nursery stock showing any signs of this scale should be discarded. Bearing trees showing any serious infestation should be given one thorough application of lime sulphur as for San Jose scale. Apply it in the spring as growth starts.

Cherry Fruit-flies.—Where injury from these result, it is the work of the white maggot stage in the fruit. In the east these maggots do much damage to cherries but in this state it is seldom that they are found in the fruit. Where cherries are found to be wormy it is usually the work of the footless grub of the plum curculio as discussed earlier under apple insects. The fruit flies feed on sweets for a time after emerging in the spring and later deposit eggs in the green fruit. To control the pest therefore a small quantity of a poisoned sweet syrup, consisting of four pounds arsenate of lead to one hundred gallons of water sweetened with cheap molasses may be sprayed or sprinkled on the cherry foliage at the time the flies are emerging. Some claim that one or two applications, of two pounds of powdered arsenate of lead to fifty gallons of water, to the foliage just as the flies are emerging gives results.

INSECT PESTS OF GRAPES

In this state the grape scale, leaf-hopper, various leaf feeding beetles and caterpillars, fruit worm and curculio are the more troublesome pests on grape in the nursery and vineyard. Unfortunately the grape is not grown as abundantly in the states as it should be. However, as a consequence of this the insect problem on grape is not so important a one with us as is the case in large grape-growing sections of the country.

Grape Scale (*Aspidiotus uvae*).—Not infrequently in the vineyard this small armored scale injures or kills grape vines outright. It works on the canes more or less protected by the loose bark on the older growth. Where injurious, it can be controlled by pruning and spraying, when the vines are dormant, with lime sulphur solution diluted with eight parts of water as for the San Jose scale. Where the loose bark is abundant tear it away before spraying. In some cases San Jose scale, which is a close relative of the grape scale attacks and destroys grape vines in this state. In the nursery grape scale is of no serious consequence.

Grape Leaf-hopper (*Typhlocyba comes*).—This small yellow and red marked leaf-hopper is common on grapes and related vines every year, seriously injuring the foliage and thereby affecting the growth of the vines and the crop. The nymphs and adults extract sap from the lower surface of the leaves causing them to appear specked with white spots and where the injury is severe the leaves turn brown and drop prematurely. This is perhaps the most common and most injurious pest of grapes in this state.

The pest passes the winter in the adult winged stage in rubbish in the vineyard or nearby along fences or where dry grass, leaves or other protection is found. Early in the spring the adults may extract sap from other plants until the grape foliage develops when they attack it and lay their eggs in the lower surface of the leaves. Virginia creeper on buildings is also similarly attacked. In Missouri several generations are developed each year, the pest becoming more abundant and injurious toward fall.

CONTROL.—Clean culture in and near the vineyard especially in the winter to destroy the overwintering adults is the first practical treatment to apply. When the pest is abundant spray with nicotine sulphate using one-half pint to fifty gallons of water when the early brood of nymphs begins to appear on the lower surface of the leaves. Use a penetrating mist spray and make sure that the lower surface of the leaves are thoroughly sprayed. If not entirely effective repeat it later for succeeding generations of nymphs. It is not effective in killing the winged adult. Sticky shields have now largely given way to sprays. In the nursery the pest can be very effectively controlled with the nicotine spray.

Leaf-feeding Beetles and Caterpillars (*Spp.*).—In Missouri, the rose chafer and the grape-vine flea-beetle are the two most important beetles attacking grape foliage. . The grape root-worm and the adult leaf-feeding beetle is present but thus far has done no appreciable injury. Of the caterpillars, the leaf-folder, the eight-spotted forester, and the plume-moth are most commonly found injuring the foliage of grape. A number of other species feed on grape but only rarely destroy much foliage. In the nursery the leaf-roller is usually the only species that requires attention.

CONTROL.—Where the foliage of grape is being injured by chewing insects one or more applications of an arsenical spray will usually destroy the pest and save the foliage and fruit. In case of the rose-chafer poison sprays are less effective. For this pest use three pounds of powdered arsenate of lead and two quarts of a cheap grade of molasses to fifty gallons of water. The molasses hides the taste of the poison and the stronger spray will kill many of the beetles. However, one should supplement the sprays with hand work as the foliage may be badly damaged in a few hours in case of a severe outbreak. Where sprays are to be applied do not wait until the leaves are folded or until the pest has done serious damage. On a few vines hand work will prove entirely effective.

Grape-berry Moth (*Polychrosis viteana*).—This small caterpillar is more or less injurious every year on the fruit. . It is to the grape what the codling moth is to apple. There are normally two generations a year. The winter is passed in the pupa stage on the grape leaves. The adults emerge and lay eggs so that the young worms are ready to begin feeding on the young setting fruits. These mature and the second generation of worms work on and in the fruit toward ripening time.

The caterpillar varies in color from greenish-brown to purple and when full fed is nearly one-half an inch long. The adult is smaller and darker than tho somewhat resembling the codling-moth in general wing markings. The presence of the pest on grape is easily detected by the reddish blotches on unripe fruits and the small worm feeding inside the fruit or where two fruits touch.

Control.—Where this pest is injurious an arsenical spray, combined with Bordeaux mixture for grape diseases, should be applied just after the blossoms are off and young fruits begin to set well. It is well to repeat this in 10 days and where injury is especially severe spray again early in July just as the worms of the second generation begin to hatch and attack the fruit. One pound of powdered arsenate of lead in fifty gallons of 4-5-50 Bordeaux should be used.

Supplement the sprays each year by gathering and burning or plowing under all grape leaves in the late fall.

Grape Curculio (*Craponius inaequalis*).—This small snout beetle is often very injurious to the fruit, especially in the southern part of the state. There is one main generation each year. The beetles begin making egg punctures after the fruits are about half grown and may continue until the earlier varieties ripen. The adult feeds to some extent on the foliage and where arsenical sprays are applied at regular intervals to keep poison on the foliage the pest can be successfully controlled. The adults pass the winter in rubbish, so clean culture in and near the vineyard during the fall and winter will reduce the number of adults that appear in the vineyard the next summer. The second spray for the grape-berry worm will help materially with the curculio.

In Missouri our larger nurserymen grow comparatively little of their grape stock so that the nurserymen's problem of handling insect pests on grape stock is a comparatively small one as compared with other types of nursery stock.

INSECT PESTS OF GOOSEBERRY AND CURRANT

Only three insects are of special importance on gooseberries or currants in Missouri. The San Jose scale is often found on currants and the imported currant worm and currant louse are to be met with every year. The various other insects reported as attacking the stems, foliage and fruit have in the past been of little importance in this state.

San Jose Scale.—In the nursery and in the garden currants may become infested with the scale and it soon proves fatal to the bushes. Dormant sprays as on fruit trees will control it. Infested plants in the nursery should be promptly destroyed.

Imported Currant Worm (*Pteronus ribesii*).—Every spring as soon as the leaves of gooseberry and currant are out the dark wasp-like adult appears to place her eggs in the veins of the leaves. The pest passes the winter in the cocoon usually as the larva and the adults appear early. The eggs hatch in about ten days and the young worms begin to eat holes in the leaves usually down in the center of the bush where they are less easily seen. As the worms increase in size they devour all edible parts of the leaves often leaving the bare stems with partly developed fruits and leaf stem. The common green and black spotted worms are familiar to all who grow currants and gooseberries. When full grown the larvae are three-fourths an inch long and spin a small oval cocoon near the ground or under rubbish on the ground. A second and even a third generation is said to develop but in this state the only damage done is due to the work of the spring brood of larvae.

Control.—This pest is easily controlled. Dust or spray with arsenate of lead as soon as the foliage is well out and no damage will be done by this pest. Too often one waits until the worms show up and by that time usually considerable damage has already been done.

Currant Louse (*Myzus ribis*).—This louse in recent years has done considerable injury to foliage especially of currant in this state. Its presence is easily detected by the appearance of reddish blotching on the surface of infested leaves. Where the lice are feeding on the lower surface of the leaves they cause an upward projection of the surface of the leaves or a pocket-like formation. Except in severe cases the leaves do not crumple up or develop knot-like formations. On currants the lice appear shortly before the fruits begin to ripen in this state.

CONTROL.—As with other plant lice one or two thorough applications of nicotine sulphate will give relief. If a sprayer is not at hand double the strength of the nicotine solution and apply it to the lower surface of the leaves with a wisp of grass or dip the infested shoots where they are not bearing fruit.

Here again much of the gooseberry and currant stock used in Missouri is propagated in the east and north. The Federal regulations affect the movement of currants from state to state, since it may carry the white pine blister-rust. These regulations are given in full in Missouri Agricultural Experiment Station Circular No. 99.

INSECT PESTS OF BLACKBERRIES AND RASPBERRIES

In Missouri the red spiders, which are not true insects, and the snowy tree-cricket are the only pests that attract special attention on blackberries and raspberries. The rose scale may at times do some injury. The nurserymen, however, are also interested in the two important plant diseases, namely, anthrachnose and blackberry rust, since both these can be spread on nursery-grown plants and both are classed as dangerously injurious diseases by the various state nursery inspection departments.

Red Spiders.—The common red spiders are very small mites related to common spiders and to the scab or mange mites of live stock. When they cause trouble on blackberries or raspberries, it is due to favorable, dry, hot, climatic conditions. In a normal summer in this state no injury results but in dry summers these crops often suffer severely. The red spider spins some silk as protection and usually feeds on the lower surface of the leaf. The epidermis is broken and the liquid content of the leaf cells is consumed resulting in a yellowing of the leaf in spots and eventually its complete drying up.

CONTROL.—Where mites cause trouble and a liberal supply of water can not be applied to the affected patch, dust with powdered sulphur when the dew is on.

Snowy Tree-cricket (*Oecanthus nigricornis*).—This small active white cricket is common in the state and at times may do considerable damage to the young raspberry canes that are to produce fruit the following summer. However, it is of much less importance with us than various reports show it to be in other parts of the country. Where injury results it is due to the work of the female in placing her eggs in the canes. This results in a splitting and dying of many canes where extensive oviposition occurs. The eggs are deposited in the fall, they hatch the following spring and the nymphs feed all summer on the foliage of different plants before maturing to deposit eggs for the following year's crop of young.

CONTROL.—Where this pest is troublesome remove and burn injured canes containing the overwintering eggs. Also practice clean culture in and near the patch thruout the year.

INSECT PESTS OF STRAWBERRIES

In this state strawberries may be attacked by a large number of insects and diseases but the root louse, leaf-roller, slugs, weevil, crown-borer, tarnished plant bug and white grubs are the most important. Some years the leaf-roller may practically ruin the crop over the important strawberry belt of the states. To nurserymen, the louse, leaf-roller and the leaf-spot disease are of special importance, since they may be spread on the young plants.

Root Louse (*Aphis forbesi*).—This louse has been reported as injuring strawberry fields in the state but it has not shown up in any of the fields where

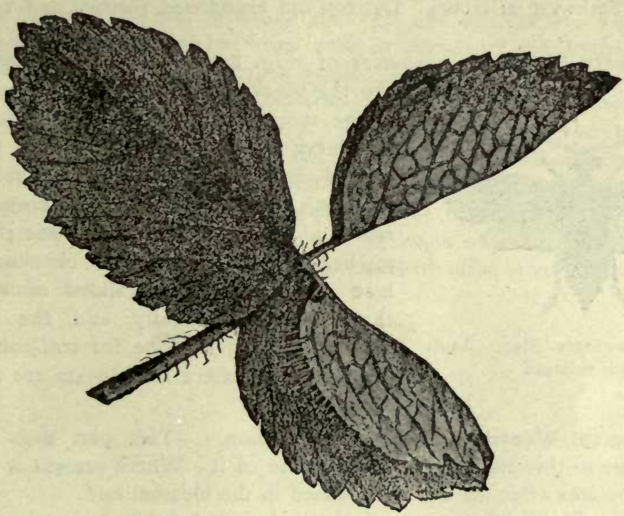

FIG. 32.—Strawberry Leaf-roller; strawberry leaf showing leaflet folded by pest

plants have been grown for distribution. In the early part of the season the lice hatching from overwintering eggs on the foliage feed by extracting sap from the young growth but later ants carry them underground where they feed on the root system. Where the lice cause trouble in strawberry patches care should be taken not to spread infestation on plants shipped to growers. Dip plants in nicotine solution before setting in the spring and spray infested patches after the overwintering eggs hatch and before lice are carried to the roots by ants. Also destroy old strawberry beds as they may serve as breeding places for lice and other pests of strawberry.

Leaf-roller (*Ancylis comptana*).—This small active caterpillar has been the most destructive pests of this crop in recent years in the state. It may also attack raspberries and blackberries. The insect is multiple brooded, having probably four broods a year in the southern counties of the state. However, the big damage comes before and at picking time. The winter is passed apparently largely in the larval stage. The moth expands slightly more than one half an inch and when seen on wing has a brownish appearance, the fore wings being also marked with lighter and darker streaks. The strawberry grower readily detects these in the patch and speaks of them as brownish moths or millers.

CONTROL.—Arsenical sprays are effective if applied at the right time. Watch for the appearance of the moths early in the spring usually the latter half of April in the southern strawberry belt, and spray promptly with two pounds of arsenate of lead powder to fifty gallons of water. The plan is to poison the young worms before they have folded over the two halves of the leaflets as protection while feeding. If this early spray is not effective repeat it after the crop is off and the next broods of moths appear in the patch. Some practice mowing and burning over patches after the crop is off. Where this is done it should be so timed as to catch the pest in the pupa stage about the last week in July in southwest Missouri. Destroy old abandoned patches and volunteer plants.

Strawberry Slugs.—Two species of slugs are reported on strawberries, tho the black-marked species (E. maculata) is the more important in this state. It is the larva of a sawfly related to the imported currant-worm. The larvae begins to attack the foliage when the crop of berries is about half developed. One thorough application of two pounds of arsenate of lead powder to fifty gallons of water at that time will usually end the trouble. This spray and the one for leaf-roller may be combined where both pests are at work on a patch.

FIG. 32.—Strawberry Slug; Adult much enlarged

Strawberry Weevil (*Anthonomus signatus*).—This pest does not do much damage in this state tho some complain of it. Where present it cuts the stems of blossoms after the egg is deposited in the blossom bud.

CONTROL.—Clean culture in and about the patch with the setting of new patches often and the plowing under of old patches will usually control this pest. It attacks only the staminate varieties but commercial growers select commercial varieties, be they varieties subject to attack or those immune to attack.

Tarnished Plant-bug.—This plant-bug breeds in the strawberry patches and the overwintering adults often do serious damage to the crop. They attack the blossom buds and young fruits causing them to be imperfect or as the grower terms it "buttoning" of the fruit.

CONTROL.—Clean culture in and near the patch during the winter as well as the summer will reduce the number of adults to pass the winter in the patch or nearby and thus reduce early spring injury. Systematic driving of the pest with the wind early in the spring is suggested also as a means of lessening the injury to strawberries the same as in case of budded nursery stock. Sprays and hand gathering is impractical in the commercial field.

Crown Borer (*Tyloderma fragoriae*).—This beetle breeds abundantly in the crowns of older plants doing considerable damage. New plantings and fields reset often do not suffer. Keep down volunteer plants and plow under abandoned patches. The beetles are unable to fly, so new fields should be set at some distance from old ones using only young plants. Those distributing plants should sell only the young plants which are not infested.

White Grubs (*Lachnosterna spp.*).—In recent years numerous complaints of white grubs have come from strawberry growers. They attack the roots, weakening or killing the plants. Often where sod is plowed under and strawberries planted in the ground serious injury may result. Where old fields are not abandoned and new ones set often enough the brown June beetles, the adults of the white grubs, may visit strawberry fields and deposit their eggs thus starting an infestation. Some species of white grubs may feed as grubs for two or three seasons.

CONTROL.—Set new fields on uninfested, cultivated soil and replant often enough to prevent this pest becoming abundant and injurious to the crop.

In this report no effort has been made to discuss all the thousands of insects which may attack the various fruits. Only those, which for the past ten or twenty years have been of most serious injury to nursery stock and the bearing fruit crops, have been included. Fruit growers and nurserymen, therefore, who have trouble with species not discussed herein, should communicate with the Agricultural Experiment Station, Columbia, Missouri and the pest will be investigated, if a new important one, or information on its control promptly given. Investigations are now being made of a number of the pests discussed herein and when completed the results of these studies will appear in full in future station publications.

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AN INVESTIGATION OF THE DIPPING AND FUMIGATION OF NURSERY STOCK

A lot of condemned apple trees

COLUMBIA, MISSOURI
DECEMBER, 1920

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

[1]In service of U. S. Department of Agriculture.

*On leave of absence.

An Investigation of the Dipping and Fumigation of Nursery Stock

K. C. SULLIVAN

More than one hundred years ago the first nursery was started in Missouri. At that time Missouri was a part of the Great West and was settled mostly along the water courses. The fruit industry at that time was undeveloped. Today there are in Missouri more than one hundred nurseries. One of the largest, if not the largest, nurseries in the world is located in Missouri and the acres of some of the others run well up into the hundreds. The growth of the fruit and nursery industry in Missouri has been remarkable. Also, the increase in the number of injurious insect pests of the fruits has been equally as remarkable; in fact, they have increased so rapidly that in some sections farmers are abandoning the fruit industry and entering some other line of work in which insect pests are not so troublesome.

Some of the most injurious insect pests and fungous diseases of fruit trees, that we have to contend with, were first introduced and scattered over the country on nursery stock. The most noted and most injurious one of these is the San Jose scale. This scale is so destructive that every state in the Union and the Federal Government have passed stringent laws regarding its distribution and control. Missouri has a law which forbids anyone in the State to distribute or dispose of nursery stock of any sort upon which there is San Jose scale; nor is anyone from outside the state allowed to ship infested plants into the state. In many states there is a law which requires that all plants badly infested with San Jose scale be destroyed and that those which are not visibly infested be treated with the best known remedies for the destruction of the scale.

The San Jose scale has become so widely distributed in Missouri that strong measures have been taken to stop further distribution. It is usually carried from one section of the country to another upon nursery stock. Practically all original infestations in Missouri were started from scale brought into the community upon nursery stock. Since the San Jose scale is usually carried into a non-infested district upon nursery stock, the logical thing to do is to produce clean stock; that is, nursery stock upon which there is no scale. This is very difficult to do, especially where the scale has once obtained a foothold.

From time to time, various remedies have been recommended by which nursery stock can be treated and the scale destroyed. Some of these treaments killed the trees as well as the scale; others did not always kill the scale, and others cost so much that they were not practical, especially with the smaller nurserymen.

During the past five years the writer has been constantly in touch with all the Missouri nurserymen and it has been his pleasure to make personal visits with practically every nurseryman in the state and, especially with those located in communities where San Jose scale is prevalent. He has worked with them and helped them treat their nursery stock for scale and other injurious insects. While engaged in the work, many problems, confronting the nurserymen, concerning the eradication of San Jose scale from nursery stock, have been brought to his attention. As a result, a number of experiments have been made to test the effect of the different materials commonly used upon infested and non-infested stock, with the object in view of determining which remedy is the most practical from all standpoints, under Missouri conditions.

Life cycle of San Jose scale.—The mature San Jose scale is yellow with a sac-like body which is covered with a soft, waxy secretion—the scale. This covering serves as a protection for the pest. The insect passes the winter in a half-grown stage, all other stages being killed by winter conditions. These half-grown insects are found under a small black scale just visible to the naked eye. About 95 per cent or more of these are male insects, they being greatly in excess. About the first of May, the males pupate and in a short time emerge as delicate two-winged insects. The females at this time have arrived at the stage of impregnation and in a few days the males disappear. The females reach maturity about a month later and begin to give birth to living young.

Most of the other scale insects deposit eggs which later hatch, but this is not true of the San Jose scale. The young are developed in a membranous sac which corresponds to an egg, but they usually burst out of this before being born. Thus the San Jose scale is usually ovivivIparous, but it may be partially oviparous. A single female is capable of giving birth to 600 young in a period of about six weeks. It is doubtful, however, if a female gives birth to more than 100 or 200 insects and many of these are males. Even at this rate of reproduction, from one single female the total number of off-spring at the end of a season reaches into the millions. The newly born insects are very tiny, yellow in color and have six legs. They soon push their way out from under the scale of the mother and crawl around for a day or so finding a suitable place to settle down. On the apple the young scale seem to push out towards the tender growing tips to settle down, while on the peach they stay more on the old wood. It is at this stage, while the young are crawling about, that the pest is likely to be scattered from one place to another upon the feet and bodies of birds, beetles and other objects. If the branches of two trees intermingle, the young easily crawl from tree to tree and it is often in this manner that the pest spreads.

When a suitable place is found, the young settle down and begin to work the long proboscis, which is three or four times the length of the insect's body, into the tissue of the host and begin developing a scale covering. Within two or three days, this covering of cottony and waxy fibers becomes matured into a pale grayish scale which gradually becomes darker.

Male and female scales are similar in size, shape and color until the first molt, which takes place in from twelve to fourteen days after the emergence of the larva. Up to this time the male and female are indistinguishable in appearance, but after the first molt they lose all resemblance to each other. The females lose their eyes, legs and antennae and become almost circular with indistinct segments. They resemble very much a minute flattened, yellowish sac. Springing from beneath the body, near the center, they have a set of long needle-like mouth parts with which they obtain nourishment from the plant. After the first molt, the male insects change in appearance also. They lose their legs and antennae but instead of losing their eyes they develop large purple ones and they become elongated and pyriform in shape. At this time the scale covering of the body of both sexes has a decidedly grayish tint mixed to some extent with yellow.

In about eighteen days after birth, the male changes to the pro-pupa or first pupal condition and the scale covering assumes a longer shape which sometimes tends to be curved. At this stage the male begins to look more like an insect. Two or three terminal segments can be seen, the posterior one bearing two short spines. The antennae, legs and wing pads are visible. The purple eyes are set close together.

About two days later, or about twenty days from birth, the male insect transforms to the true pupa. The matted skin at this time, instead of forming a part of the scale covering as in the preceeding molt, is pushed out from beneath the scale. The last or third molted skin is also pushed from beneath the scale.

The male insect becomes mature in twenty-four to twenty-six days from birth and pushes out backward from beneath the scale.

In from three to five weeks from the larva, the females molt the second time. The skin splits around the edge of the body. The upper half adheres to the scale covering and the lower half forms a sort of ventral scale between the insect and the bark. The female insect becomes full grown in from thirty to forty days from birth.

The adult male insect appears as a very small, delicate, two-winged fly about 0.6 mm. long and is capable of flying from place to place. The mature female does not develop as the male does, but remains concealed beneath her scale as a small, yellowish, almost circular insect about 0.8 mm. wide and 1 mm. long. No eyes, legs, wings or antennae are developed.

The scale covering of the female is almost circular and slightly raised in the center. The exuvia is central or nearly so. In diameter the scale varies from 1 to 2 mm. The color of the scale is gray, excepting the part covering the exuvia, which is a pale or reddish yellow and the ring effects, which are often noted between the center and outer edge of the scale, marks the edges of the molts of the larval scale.

The scale covering of the male is darked than that of the female and especially in the winter, when it is black. In shape, it is oblong-oval and just about half as wide as long. It ranges from 0.5 to 1 mm. in length. There is a nipple-like prominence located between the anterior margin and center of the scale which marks the position of the larval scale.

In Missouri there are four generations a year and probably five, especially in a favorable season. The generations overlap to a great extent.

Owing to the smallness and the color of the scales, the insect is hard to detect by the untrained eye and in many cases the writer has known the lenticles, or small knots on a tree, to be mistaken for the San Jose scale.

When a plant becomes encrusted with the insects, it looks grey in color and upon rubbing the hand along the trunk or branches large flakes of the dead scales become loosened and fall off. The tree looks sick and does not leaf out so early in the spring as a normal tree and usually dies within a season or two. Where there is only a scattering of scale on the plant, it can usually be detected by the sunken places in the bark caused by a lack of food material which has been used by the insect instead of by the tree. Also immediately around the scale the bark takes on a reddish tinge, which is supposed to be caused by a toxin which the insect injects into the plant. This red-like blotch is very characteristic of the San Jose scale, especially on the apple and peach.

Damage.—It is impossible to estimate the amount of damage done by the San Jose scale in Missouri orchards because at present no one knows exactly how extensively Missouri is infested, but it is a known fact that many large commercial and small orchards have been completely destroyed

Some poorly packed nursery stock. This stock was also infested with San Jose scale. It was found and condemned thus preventing its distribution

by it. However, in the nurseries of Missouri in the past two years, the damage caused by this insect has amounted to the tremendous sum of $20,000.00 and this is but a drop in the bucket as compared with the damage to the orchards in Missouri.

Control in the orchard.—The San Jose scale can be controlled in the orchards if proper precautions are taken. The most successful method practiced today is the use of lime-sulphur as a dormant spray. Certain of the miscible oils are also used to a greater or less extent with good results. Commercial lime-sulphur can be purchased on the market, which, when mixed with water, one gallon of lime-sulphur to seven gallons of water, makes a most efficient spray.

A miscible oil makes a good spray when mixed with water at the rate of one gallon of the oil to twelve gallons of water. The lime-sulphur spray is the cheaper spray of the two and is recommended by the United States Department of Agriculture, and by the state experiment stations.

As the San Jose scale is a sucking insect, it is impossible to destroy it by using a poisonous spray, so a contact spray must be used. The spray must be strong enough to either destroy the scale outright, that is, consume its body, or have great penetrating power, like the oil emulsions which burn and smother the insects.

According to Lodeman, lime-sulphur spray was first used for the control of insects in 1851, by a Frenchman by the name of Grison, a gardner at Versailles, France. Grison used the following formula at first but later reduced the amount of lime to half.

Flowers of sulphur	500 gms.
Freshly slaked lime	500 gms.
Water	3 liters.

Boil for ten minutes, draw off the clear liquid and use 1 to 100 parts of water. This mixture was used as a fungicide and is one of the few early spray preparations still in use.

Regarding the first use of lime-sulphur washes in America, Lodeman says: "A mixture similar to the following was originally used in California as a sheep dip, but as fruit trees began to drive out the sheep, the applications of the compound were transferred to the trees, and thus it has been very generally used, and has proved to be of value in the orchards as well as on the sheep. It is used against insects and fungi.

Lime (unslaked)	25-40 pounds
Salt	15 pounds
Sulphur	20 pounds
Water	60 gallons

"To mix the above, take 10 pounds of lime, 20 pounds of sulphur and 20 gallons of water. Boil until the sulphur is thoroly dissolved. Take the remainder, 15 pounds of salt and 15 pounds of lime, slake and add enough water to make the whole 60 gallons. Strain and spray on the trees when milk warm or somewhat warmer. This can be applied when the foliage is off the tree and will have no injurious effect upon the fruit buds or upon the tree itself."

Marlatt says "the early experience with lime-sulphur and salt washes for San Jose scale was unfavorable, largely due apparently to the fact that the observations on the trees treated were not continued long enough to note the effect of the late summer results. Good results were obtained with the kerosene emulsions and particularly with the soap washes and the fish-oil soap washes."

The formula which is commonly used at the present time in making home made concentrated lime-sulphur solution is as follows:

Lump Lime	40 pounds
Sulphur	80 pounds
Water	50 gallons

About 10 gallons of hot water is added to the sulphur and thoroly stirred. The lime is then added. As the lime slakes hot water is added as necessary to, prevent caking. When the lime has completely slaked enough hot water is added to make 50 gallons and the solution boiled for an hour and kept constantly stirred. Water is added from time to time to keep the liquid up to 50 gallons. This concentrated solution should test about 31 degrees Beaumé. It should be stored in tight barrels until ready for use. When used it is diluted with water in the same manner as the commercial lime sulphur.

Hydrocyanic-acid gas was also tried in controlling San Jose scale on orchard trees, and at present is used upon citrus trees for controlling citrus scale. Where care was taken this method proved quite successful when used on the deciduous fruit trees, but the cost of fumigating an orchard as compared with spraying was so great that the former method has been abandoned altogether. An air-tight box had to be constructed in such a way that it could be moved from over one tree to another, or a large tent had to be placed over the tree to be treated and the gas generated beneath. Each tree had to be treated for about one hour.

The treatment for San Jose scale must be applied while the tree is in a dormant condition for the scale is so difficult to kill that a treatment, to be effective, must be made so strong that it will also kill foliage. While the tree is in a dormannt condition, the insects are easily reached and a strong spray can be applied without any fear of damaging the foliage. Also, as the insects pass the winter in a half-grown state, they are more easily killed during the dormant season.

In applying a spray for the scale, thoroness of the application is of the utmost importance. If twigs here or there are left without a coat of the spray material, the insects which are on them will soon reinfest the tree.

At the present time the standard spray for the control of the San Jose scale upon deciduous orchard trees is lime sulphur. Commercial concentrated lime sulphur has a specific gravity of approximately 1.28. One gallon of it is used to seven gallons of water which reduces the specific gravity to 1.04. This solution is then applied with either a barrel or power spraying machine during the dormant season.

Besides controlling the San Jose scale with a dormant spray of lime-sulphur, many other pests, such as Forbes scale and aphids are also controlled.

One of the important reasons why the San Jose scale is difficult to control is the fact that it attacks so many of the deciduous plants including fruits, ornamentals and shade trees.

Control on nursery stock.—As has been previously explained it was thru the infestation of nursery stock that the San Jose scale has become so widely distributed and naturally the first place to start in the control of the pest is upon nursery stock.

Probably the most important means of controlling the scale upon nursery stock has been the passing of laws requiring that all infested stock be destroyed and the remainder treated under the direction of a competent man.

Before 1913 Missouri had no law controlling the growing or transportation of infested nursery stock, and as a result much infested stock was sold to Missouri farmers. In 1913 an effective law was passed and has been vigorously enforced.

Every state in the Union has a law similar to the Missouri law and they have done much to prevent further spread of San Jose scale and other dangerous insect pests and diseases as well.

Practically all states require the use of hydrocyanic-acid gas in the control of the scale on nursery stock and up to the present time it is most widely used.

Some nurserymen prefer to dip their trees in a miscible oil rather than fumigate and this method has, to a great extent, been successful.

In fumigating with hydrocyanic-acid gas the trees are dug in the fall or early spring, all excessive moisture allowed to dry from the tree and then placed in an air tight box or room. The gas is generated in the room and the trees are left exposed to it for from 45 minutes to one hour. Special preparations must be made, such as building an air tight box or house, in using hydrocyanic-acid gas. The gas is very poisonous, the chemicals are costly and it is easy to make a mistake in mixing them. Under certain conditions the gas is likely to injure the stock, especially the more tender species. This is also true in using liquid dips.

Hydrocyanic-acid gas first used.—Hydrocyanic-acid gas has been used in collecting jars for years by entomologists to kill insects, but was first used for the destruction of scale insects by D. W. Coquillett in the orange groves around Los Angeles, Cal. His first work with hydrocyanic-acid gas was in September 1886, and was carried on at this time for the control of the cottony cushion scale on citrus trees. Such means as tobacco smoke, sulphur fumes, concussion from gun powder, heat, muriatic acid, carbonic acid gas, chloroform, arsenic, bisulphide of carbon and other fumes and gases were tried, but none was so successful as hydrocyanic-acid gas. Dr. F. W. Morse of the University of California also began studying the control of the cottony cushion scale in 1887 and as a result that university gave to the public, in bulletin 71, the first knowledge of the use of hydrocyanic-acid gas. In doing this first work, a tent was thrown over the tree and the gas generated beneath the tent by putting together in one vessel sulphuric acid, water and dry potassium cyanide.

All of this work done in California was upon citrus trees, which were in full foliage and a great deal of burning and injury resulted. However, the method of using hydrocyanic-acid gas has been so well perfected that at the present time it is comparatively safe to fumigate citrus trees which are infested with white fly or scale.

The California agricultural experiment station, under the direction of Morse, conducted experiments with other gases as insecticides with special reference to the white scale (Icerya purchasi). The following is a summary of the results obtained, as set forth in bulletin 70 of the California agricultural experiment station.

Chlorine, carbon bisulphide, sulphuretted hydrogen, ammonia, carbon menoxide, aloxic acid, carbolic acid and hydrocyanic-acid gas were tried and it was found that hydrocyanic-acid gas was the only one that produced sufficiently fatal effects as to warrant a more thoro determination of the time of exposure and quantities of material which would produce the best results.

Hydrocyanic-acid gas was not used upon deciduous trees until 1894, when the San Jose scale was found upon deciduous fruit trees in Charlottesville, Va. and Coquillett was detailed by the United States Department of Agriculture to conduct experiments with hydrocyanic-acid gas on these infested trees. The results of the first experiments were so satisfactory that the work was continued.

It was in 1898 that it was first suggested that hydrocyanic-acid gas could be used in mills, elevators and warehouses for the destruction of injurious insects.

Use up to the present time.—Since the discovery of hydrocyanic-acid gas as an insecticide it has been used in a number of different ways.

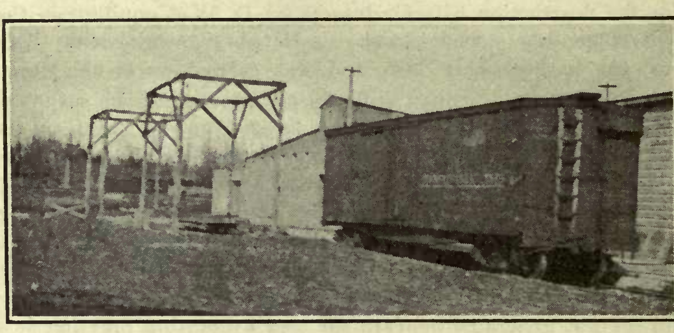
1. To fumigate citrus trees infested with all sorts of scale insects.

2. To fumigate deciduous fruit trees, including nursery stock, for the destruction of San Jose scale.

2. To fumigate deciduous fruit trees, including nursery stock, for the destruction of San Jose scale.

3. To fumigate greenhouses for the destruction of white fly, red spider and other pests on greenhouse plants.

4. To fumigate warehouses, elevators, mills and other buildings for the destruction of various insect pests.



Apparatus for fumigating car load lots: A tight oil canvas is placed over the frames. The hydrocyanic acid gas is generated in a tank and conducted through a pipe to the enclosure

5. To fumigate dwelling houses, railroad coaches, street cars, hotels and similar places for the destruction of lice, bedbugs, clothes moths and household pests.

The use of hydrocyanic-acid gas as a fumigating material is becoming more extensive and the United States Department of Agriculture and all of the state experiment stations recommend it.

Method of using.—The most general method practiced at the present time in using hydrocyanic-acid gas is as follows:

One fluid ounce of sulphuric acid having a specific gravity of at least 1.83 is poured into an earthenware crock, wooden bucket or tub, containing 3 fluid ounces of water. Into this mixture 1 ounce, by weight, of fused cyanide of potassium, 98-99 per cent pure, is added. The above amounts are used for every 100 cubic feet of space. In fumigating tender growing plants, the above formula is too strong and has to be weakened. For dormant trees, mills, elevators and the like the 1-1-3 formula is recommended by both the United States Department of Agriculture and practically all of the state experiment stations.

In fumigating nursery stock an air tight box or house is necessary.

The trees are placed in the box or house. The water and sulphuric acid are mixed in an earthen jar and the jar placed in the box or house. The potassium cyanide is then dropped in and the box or house closed just as quickly as possible. The hydrocyanic-acid gas which is generated is deadly poisonous and the person doing the fumigating must be very careful not to breathe any of it. It requires about 45 minutes to fumigate nursery stock, altho some authorities say that better results can be obtained by letting the stock remain an hour. At the end of this time the fumigating box or house is opened and the gas allowed to escape and in from 15 to 20 minutes the trees can be safely removed.

It is never advisible to fumigate trees while they are damp or wet. It is claimed that under such conditions the gas is more likely to injure the stock. However, the writer's experiments to date fail to corroborate this, though they do show that less scale is killed under those conditions.

Some states require by law that all nursery stock grown within its borders or shipped in from outside nurseries be fumigated and, as a result, all of the larger nurseries in the United States have constructed special fumigating houses or boxes.

Chemical composition of hydrocyanic-acid gas.—In fumigating work hydrocyanic-acid gas is generated, as has already been explained, by placing together potassium cyanide (KCN) sulphuric acid (H_2SO_4) and water (H_2O).

The sulphuric acid, which is sold commercially, has a strength known as 66° Baumé which corresponds to the 96 per cent pure sulphuric acid. Commercial sulphuric acid, however, contains some impurities and is seldom more than 93 or 94 per cent pure.

The potassium cyanide which is purchased on the market runs about 98 per cent pure.

When the sulphuric acid and the potassium cyanide are brought together, the chemical reaction that takes place is as follows:

$$2\ KCN + H_2SO_4 = K_2SO_4 + 2\ HCN$$

In the above reaction, 1 ounce (avoirdupois) of potassium cyanide (100 per cent pure) requires 0.75 ounce (avoirdupois) sulphuric acid or .81 ounce of commercial sulphuric acid containing 93 per cent sulphuric acid which would be equal to 0.42 fluid ounces.

Under conditions met with in fumigating work, the above reaction cannot be obtained and result in the best yield of hydrocyanic-acid gas. More sulphuric acid must be used and this causes acid potassium sulphate to be formed as is shown in the following equation:

$$KCN + H_2SO_4 = KHSO_4 + HCN$$

In this reaction 0.84 fluid ounce of 93 per cent sulphuric acid is required for each ounce (avoidupois) of potassium cyanide. This amount in round numbers equals 1 part cyanide to 1 part acid which gives the best results in field work. In order to get the best yield of hydrocyanic-acid gas only two parts of water should be used, but in field practice when only two parts of water are used, the residue in the generating jar often solidifies and in order to prevent this, three parts of water are used. Thus the 1-1-3 formula is used in fumigating nursery stock.

RESULTS OF EXPERIMENTS WITH HYDROCYANIC-ACID GAS

Because of the large amount of damage being done in Missouri by the San Jose scale, and in order to help the fruit grower and nurserymen to better control the scale and thus lessen the danger of further dissemination of the pest, the writer began a series of experiments in the fall of 1915 with reference to the control of the scale upon nursery stock.

Some of the nursery stock in the state which was found to be infested with San Jose scale was brought to Columbia where the experiments were conducted.

The primary object of the investigation was to determine if possible the most practical, efficient and cheapest method to use in controlling the scale on nursery stock with the least injury to the trees or plants.

In Missouri there are a number of nurserymen who grow nursery stock on a small scale and do not care to go to the expense of building an expensive fumigating house or box and besides many object to using hydrocyanic-acid gas because of its very poisonous nature. Several of these nurserymen have asked repeatedly about the possibilities of dipping nursery stock in a lime-sulphur wash or a miscible oil for the control of San Jose scale.

Some of the nursery stock which was used in the experimental work at the Missouri Agricultural Experiment Station

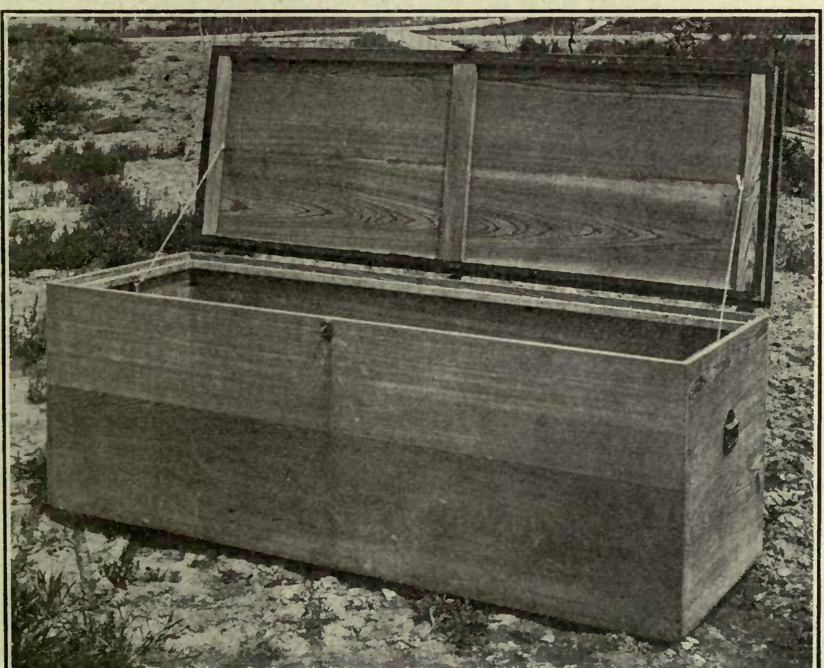
Method of procedure.—First, during the fall of 1915 the following number of fruit trees and plants were obtained: Apple, 356 trees; peach, 164; pear, 52, and plum, 52. All of the fruit trees were two years old. Of the apple trees obtained, 260 were heavily infested with San Jose scale and 86 of the peach trees were also heavily infested. The trees were dug in the fall after the leaves had fallen and shipped to Columbia. Most of the scale-infested trees showed marked weakness caused by the ravages of the pest; otherwise all of them were in good condition. The trees were heeled in the fall and left until March 21 and 22, 1916, when they were given the different treatments. None of the trees died during the winter.

The work was continued during 1917. On April 5, 1917, the following two-year-old trees were obtained, all of which were heavily infested with

San Jose scale: Apple, 58 trees; peach, 58, and plum, 5. These trees had just been dug from the nursery row. They showed weakness from the effects of the scale, but were otherwise in excellent condition. A part of these trees were treated with hydrocyanic-acid gas on April 10, 1917.

In the spring of 1918 a small nursery was started on the experimental grounds at Columbia for the purpose of obtaining trees to continue scale control investigations. Both peaches and apples were grown and in the summer of 1919 scale infested trees were placed with them and by fall the stock was all heavily infested. In March 1920 these trees were used in fumigating and dipping experiments.

As has already been explained, one fluid ounce 66° Baumé sulphuric acid, 1 ounce potassium cyanide and three fluid ounces of water for 100 cubic



Fumigating Box used at the Missouri Agricultural Experiment Station. Notice the cleats against which the lid fits. These cleats are covered with felt to prevent the escape of gas.

feet is most commonly used in fumigating nursery stock. Some of the nurserymen of Missouri had complained of severe burning of the stock when used this strong so two strengths of hydrocyanic-acid gas were used in the work in 1916. The regular 1-1-3 formula was tried and a formula just half as strong (½-½-1½) was also tried.

A fumigating box was constructed from 1 inch cypress lumber. The box was made 7 feet long, 3 feet wide and 2 feet deep, having a total capacity of 42 cubic feet. The top of the box was hinged on so as to form a lid. Cleats were nailed on to the lid so as to fit tightly against the inside of the box when closed and these cleats were covered with felt so as to make the box just as nearly air tight as possible.

The number of plants to be treated dry with the 1-1-3 formula were dug, the dirt removed from the roots and placed in the box. The sulphuric acid was weighed out and placed in an earthen jar, then the required amount of water was added slowly so as to prevent sputtering. The jar was then placed in the bottom of the fumigating box in such a way as not to come in contact with the nursery stock. The potassium cyanide, 98 per cent pure, which had been broken up into small pieces, was then added to the mixture and the lid quickly closed and clamped down. The stock was allowed to fumigate for 45 minutes, when the box was opened, the gas allowed to escape, which took about 10 to 15 minutes. The plants were then removed and set about two feet apart in rows 3 feet apart. The residue left in the jar is very poisonous so it was removed and buried to prevent anything from getting hold of it.

Just as soon as the set of trees were removed from the fumigating box, a second set containing the same number of plants was taken. This set of plants was treated in exactly the same way as the above set with the exception that they were thoroly dampened, both roots and tops, before being placed in the box. The object in fumigating this set of wet plants was to find out exactly if possible to what extent the plants would be injured and also if the effect upon the scale would be the same as upon the scale on the dry plants.

The third set of plants was treated exactly the same as the first except the ½-½-1½ formula was used.

A fourth set of plants, which were wet, was also treated with the ½-½-1½ formula.

Effect of hydrocyanic-acid gas upon San Jose scale.—As is shown by the following table, eighty apple trees with scale, were treated with hydrocyanic-acid gas in 1916.

Table 1.—Apples Treated in 1916

Date 1916	Treatment	Condition of trees	Length of treatment, min.	No. trees treated	Per cent scale dead 5/14/16	Per cent trees dead 5/26/16	Per cent trees dead 4/4/17
March 21	HCN 1-1-3	wet	45	20	77.8	10	40
	HCN 1-1-3	dry	45	20	100	10	30
	HCN ½-½-1½	wet	45	20	72.6	10	30
	HCN ½-½-1½	dry	45	20	97.5	25	55
	Check	--------	----	20	38.9	0	60

On May 14, 1916, a count was made to determine the effectiveness of the hydrocyanic-acid gas. In making the counts on these trees, several heavily infested twigs were collected from several of the different trees. The twigs were placed under a high power binocular and the numbers of dead and live insects counted. From these numbers, the percentage of live insects was determined. On May 25, 1916, additional counts were made and on May 26, 1916, the number of trees which were dead was counted.

The results obtained show clearly that hydrocyanic-acid gas used at the strength of 1-1-3 and ½-½-1½ will kill San Jose scale on dry plants better than on moist plants. Also the dry plants suffered more from the treatment than the wet ones. The hydrocyanic acid gas gave best results when used at the rate of 1-1-3 upon dry trees. Upon the other three sets live scales were found, the larger percentage being upon the trees treated while damp. All of these trees were heavily infested with the scale at the time of treating and their vitality had been weakened a great deal and this is undoubtedly the reason why such a large percentage died. The normal mortality of scale on the check trees was 38.9 per cent and the high mortality of the trees was undoubtedly due to the effects of the pest.

On April 9, 1917, the following trees were treated with hydrocyanic acid gas, 1-1-3.

TABLE 2.—APPLES TREATED IN 1917

Date 1917	Treatment	Condition of trees	Length of treatment, min.	No. trees treated	Per cent scale dead 4/20/17
April 9	HCN 1-1-3	wet	45	8	100
	HCN 1-1-3	dry	45	8	100
	Check	-------	----	4	75

This test in 1917 was made in order to check or substantiate the results obtained in 1916. On April 20, 1917, the trees were thoroly examined for scale and no live scale whatsoever could be found on either the trees wet or dry. In comparing the above treatments with the check it is clearly shown that good results were obtained with hydrocyanic-acid gas used at the rate of 1-1-3.

On March 22, 1920, additional experiments were performed with HCN as is shown by the following table.

TABLE 3.—APPLES TREATED IN 1920

Date 1920	Treatment	Condition of trees	Length of treat- min.	No. of trees treated	Per cent scale dead 5/20/20	Per cent trees dead 11/8/20
March 23	HCN 1-1-3	wet	50	34	100	44.1
March 22	HCN 1-1-3	dry	50	34	100	50.5
March 27	HCN 2-2-6	wet	50	34	100	70.5
March 26	HCN 2-2-6	dry	50	34	100	73.5
March 29	HCN* 1-1½-3	wet	50	34	100	70.5
March 29	HCN* 1-1½-3	dry	50	34	100	50.0
	Check	-------	----	68	76	94.2

*In this treatment Sodium cyanide (NaCN) was used.

As the table shows in 1920 potassium cyanide was used twice as strong as is recommended. Also sodium cyanide (NaCn) was used. Sodium cyanide, which is stronger than potassium cyanide and which is ordinarily used at the strength of one ounce sodium syanide, one and one-half ounces sulphuric acid and three ounces water. Every treatment of cyanide used in 1920 killed 100 per cent of the scale. As to the effect of the treatments upon the trees the HCN used at the rate of 1-1-3 it seems causd less injury both upon wet and dry trees.

Effect of hydrocyanic-acid gas upon scale on peaches.—Somewhat better results were obtained on peaches. From counts made on May 25, as is shown by the table, three of the treatments gave perfect results so far as controlling the scale was concerned.

TABLE 4.—PEACHES TREATED IN 1916

Date 1916	Treatment	Condition of trees	Length of treatment, min.	No. trees treated	Per cent scale dead 5/14/16	Per cent trees dead 5/26/16	4/4/17
March 21	HCN ½-½-1½	wet	45	8	95.4	37.5	87.5
	HCN ½-½-1½	dry	45	8	100	37.5	62.5
	HCN 1-1-3	wet	45	8	100	12.5	50
	HCN 1-1-3	dry	45	8	100	87.5	87 5
	Check	--------	----	8	100	25	62.5

Hydrocyanic-acid gas used at the rate of ½-½-1½ on damp trees gave the poorest results. A larger number of the trees treated dry were dead May 26 than was the case with those treated wet.

TABLE 5.—PEACHES TREATED IN 1917

Date 1917	Treatment	Condition of trees	Length of treatment, min.	No. trees treated	Per cent scale dead 4/20/17
April 9	HCN-1-1-3	wet	45	4	100
	HCN-1-1-3	dry	45	4	100
	Check	--------	----	6	50

In 1917 hydrocyanic-acid gas proved to be effective in killing the scale on peaches upon both wet and dry trees. Fifty per cent of the scale on the check trees had passed the winter in safety.

TABLE 6.—PEACHES TREATED IN 1920

Date 1920	Treatment	Condition of trees	Length of treatment, min.	No. of trees treated	Per cent scale dead 5/26/20	Per cent trees dead 11/8/20
March 29	HCN 1-1-3	wet	50	5	100	20
March 22	HCN 1-1-3	dry	50	5	100	20
March 27	HCN 2-2-6	wet	50	5	100	100
March 26	HCN 2-2-6	dry	50	5	100	0
March 29	HCN* 1-1½-3	wet	50	5	100	80
March 29	HCN* 1-1½-3	dry	50	5	100	60
	Check	-------	----	10	85.67	100

*In this treatment Sodium cyanide (NaCN) was used.

One hundred per cent of all the scale was killed in every case in 1920.

Effect of hydrocyanic-acid gas upon San Jose scale on pear.—

TABLE 7.—PEARS TREATED IN 1920

Date 1920	Treatment	Condition of trees	Length of treatment, min.	No. of trees treated	Per cent scale dead 5/26/20	Per cent trees dead 11/8/20
March 23	HCN 1-1-3	wet	50	2	100	50
March 22	HCN 1-1-3	dry	50	2	100	0
March 27	HCN 2-2-6	wet	50	2	100	50
March 26	HCN 2-2-6	dry	50	2	100	100
March 29	HCN* 1-1½-3	wet	50	2	100	50
March 29	HCN* 1-1½-3	dry	50	2	100	0
	Check	-------	----	4	74.68	0

*In this treatment Sodium cyanide (NaCN) was used.

Practically the same results were obtained upon pear as upon peaches and apples.

Effect of hydrocyanic-acid gas upon San Jose scale on plum.—

TABLE 8.—PLUMS TREATED IN 1917

Date 1917	Treatment	Condition of trees	Length of treatment, min.	No. trees treated	Per cent scale dead 4/20/17
April 9	HCN 1-1-3	wet	45	1	100
	HCN 1-1-3	dry	45	1	100
	Check	-------	----	1	57

As to the effectiveness of hydrocyanic-acid gas upon San Jose scale, the above tables show that it might not in every case kill all of the scale, especially when used at a strength weaker than 1-1-3. When used at a weaker strength it will kill a large percentage of the insects but not enough to recommend its use.

From the summary it is readily seen that more of the trees died when treated with the stronger hydrocyanic-acid gas than with the weaker. It is a known fact that plants treated with a high strength of hydrocyanic-acid gas will be injured and if the hydrocyanic-acid gas is too strong it will kill the trees. Whether or not it takes the gas longer than a month to effect a tree enough to kill it, is not known but it stands to reason that if the gas does injure a plant, the 1-1-3 strength would cause more injury than the ½-½-1½ strength.

As has been shown, the greater strength gave better results in controlling the scale than the weaker and as far as killing the trees is concerned, there is not enough difference in the two strengths to amount to a great deal. Since the control of the scale is of the most importance, it is undoubtedly advisable to use the 1-1-3 formula when fumigating nursery stock.

Another very important thing that was brought out in this work is the effect of hydrocyanic-acid gas upon wet and dry plants. It is the general belief among nurserymen that if plants are treated with hydrocyanic-acid gas while wet, or damp, the moisture on the plant will absorb a large quantity of the gas, which in turn, will cause a great deal of burning and injury to the plant. It will be noticed that in this work, a larger percentage of those plants treated dry died than those treated wet which is contradictory to the general belief of nurserymen and experiment station workers.

A well constructed fumigating house. It is built of tongue and grooved lumber and cleats cover the joints on the outside

In treating plants with ether to stimulate growth, a larger dose of ether must be used if plants are damp or the exposure must be longer if the same results are derived as would be obtained if the plants were dry. This may also be true of hydrocyanic-acid gas and as the results obtained indicate, a larger dose of hydrocyanic-acid gas must be used on damp plants to obtain the same results as on dry plants with a smaller dose. Also, fewer scale were killed upon the damp trees than on the dry, which indicates that possibly the same thing holds true in regard to animals as to plants.

Since the scale was killed better on stock treated dry than on stock treated wet, and as the destruction of scale is of prime importance, nursery stock should not be fumigated with hydrocyanic-acid gas when wet, even tho the injury to the plants may be greater when treated dry.

CARBON BISULPHIDE FIRST USED

Carbon bisulphide was first used as an insecticide by Louis Doyère, a former professor of Agriculture at the Institute of Versailles, in 1856 and 1857. He used small amounts of the liquid on grain to destroy the weevils and their eggs. He also demonstrated that carbon bisulphide would not injure the grain. In 1876, Cornu and Moulleferet, both French investigators, demonstrated that carbon bisulphide could be successfully used upon grape phylloxera, caterpillars, butterflies, cicadas, wasps and plant lice.

Use up to present time.—After 1876 the popularity of carbon bisulphide as an insecticide became great and many experiments were carried on with it. It was found to be an effective and cheap insecticide and easy to use. Today carbon bisulphide is widely used for the following:

1. To kill grape phylloxera on the roots of the grape.
2. Root maggot of different sorts on the roots of different plants.
3. For destruction of ants.
4. To kill grubs and mole crickets.
5. For the destruction of burrowing animals, such as moles, prairie dogs, gophers, etc.
6. For the destruction of sucking insects upon small plants.
7. For fumigating buildings containing stored cereals to destroy the insect pests.
8. For destroying household pests, museum pests and similar pests.

In fact carbon bisulphide is the most extensively used fumigant today for destroying the more easily killed insects.

Methods of using.—Carbon bisulphide is easy to obtain and easy to use. Any one who is willing to take a few precautions can use carbon bisulphide with perfect safety. Carbon bisulphide is put up in tight tin cans or steel drums and can be purchased in small quantities. It is very volatile and diffuses through the air rapidly. The gas is heavier than air and this factor is taken advantage of when using carbon bisulphide. In fumigating bins containing cereals or similar places, shallow pans are usually employed. The pans are set on top of the grain or on anything near the ceiling. Better results are obtained if the place to be fumigated is made air tight and the temperature is 70°F. or above. The carbon bisulphide is poured in the pans, the doors closed and the cracks stopped so as to prevent the gas from escaping from the building. Different authorities vary as to the rate at which carbon bisulphide should be used. In Kansas the following amounts have been recommended and other stations report similar amounts:

At 90°F. 1 lb. CS_2 is sufficient for every 500 cu. ft.
At 80°F. 1 lb. CS_2 is sufficient for every 400 cu. ft.
At 70°F. 1 lb. CS_2 is sufficient for every 300 cu. ft.

If used in an open bin, the above amounts should be greatly increased

At a temperature below 60°F. it is not advisable to fumigate with carbon bisulphide at all for it does not evaporate sufficiently fast below this temperature.

The bin or building should be allowed to fumigate for from 36 to 48 hours.

For fumigating seeds with carbon bisulphide, from 1 to 1½ pounds should be used to every 1000 cubic feet.

Carbon bisulphide has been tried a number of times upon nursery stock for destroying scale insects, but up to the present time has proven unsatisfactory.

Chemical composition of carbon bisulphide.—According to W. E. Hinds, of the United State sDepartment of Agriculture, Farmers' Bulletin 145, "the chemical symbol of carbon bisulphide is CS_2. Its molecules consist of one atom of carbon united with two atoms of sulphur. The specific gravity of the liquid is 1.29. The vapor is 2.63 times as heavy as atmospheric air. The pure article volatilizes rapidly and completely when exposed to the air. The liquid boils at 115°F.

"The vapor takes fire in air at about 300°F. and burns with a faint blue flame, scarcely visible in daylight, but evolving considerable heat and decomposing the carbon bisulphide into carbon dioxide (CO_2) and sulphur dioxide (SO_2). The latter is the familiar gas given off by the burning of sulphur matches and is a strongly poisonous suffocating gas, which should not be inhaled. Carbon bisulphide vapor mixed with three times its volume of oxygen, or an amount of air containing that amount of oxygen, forms a mixture which is very highly explosive upon ignition. As 21 per cent of the air is oxygen, one volume of liquid carbon bisulphide evaporated in 5,357 volumes of air would form such a mixture. An atmosphere composed of one volume of carbon bisulphide vapor to approximately 14.3 volumes of air is liable to violent explosion in the presence of fire of any kind whatever, or a temperature of about 300°F. without flame. This is about the maximum danger point from explosion in the use of carbon bisulphide."

The higher the temperature, the more carbon bisulphide will be taken up by the air.

RESULTS OF EXPERIMENTS WITH CARBON BISULPHIDE

As has already been pointed out, carbon bisulphide is probably the most generally used insecticide for fumigating, especially for such insects as grain weevil. It has been tried to some extent upon nursery stock for the control of San Jose scale, but so far satisfactory results have not been reported. Carbon bisulphide is cheaper than hydrocyanic-acid gas, easier to handle and, used as a poison, does not act in an effective way so quickly which makes it less dangerous for the person handling it.

Object.—The idea in using carbon bisulphide was to determine if possible, whether or not it could be used at all for destroying San Jose scale upon live plants without injury to the plants. Owing to its cheapness and the ease with which it can be used as compared with hydrocyanic-acid gas, carbon bisulphide would be a great deal more desirable provided the same results could be obtained.

Procedure.—The same fumigating box was used with the carbon bisulphide as with the hydrocyanic-acid gas and, as shown by the following table, the same number of trees were used. The first dry and the first wet set of trees were treated for an hour with carbon bisulphide at the rate of 1 pound of the insecticide to 100 cubic feet of space. Sets No. 3 and 4 were treated for an hour also, but the carbon bisulphide was used at the rate of 1½ pounds to the 100 cubic feet.

In treating the trees, each set was placed in the fumigating box separately, as with the hydrocyanic-acid gas. Near the top of the box a shelf was constructed upon which a shallow pan was placed. The nursery stock was placed in the box, the required amount of carbon bisulphide poured into the pan and the lid closed.

Eighty apple trees heavily infested with San Jose scale were treated with carbon bisulphide as is shown by the following table.

TABLE 9.—APPLES TREATED IN 1916

Date 1916	Treatment	Condition of trees	Length of treatment, min.	No. trees treated	Per cent scale dead 5/25/16	Per cent trees dead 5/26/16	Per cent trees dead 4/4/17
March 21	CS_2 1-100	dry	60	20	92.3	30.5	70
March 21	CS_2 1-100	wet	60	20	88.2	15	50
March 21	CS_2 1½-100	dry	60	20	77.1	10	45
March 21	CS_2 1½-100	wet	60	20	83.9	10	40
	Check	--------	----	20	38.9	0	60

As is shown, counts made May 14 and 25 definitely show that carbon bisulphide used at a strength of either 1 to 100 or 1½ to 100 will not control scale. As compared with the check, however, it is evident that a number of the insects were killed but not enough to warrant its use.

On April 9, 1917, the following trees were treated with carbon bisulphide, 1½ to 100.

TABLE 10.—APPLES TREATED IN 1917

Date 1917	Treatment	Condition of trees	Length of treatment, min.	No. trees treated	Per cent scale dead 4/20/17
April 9	CS_2 1½-100	wet	60	8	96.6
	CS_2 1½-100	dry	60	8	94.6
	Check	--------	----	4	75.0

The results obtained in 1917 are practically the same as those obtained in 1916 and they also show that carbon bisulphide used at the rate of 1½ to 100 will not control San Jose scale.

TABLE 11.—PEACHES TREATED IN 1916

Date 1916	Treatment	Condition of trees	Length of treatment, min.	No. trees treated	Per cent scale dead 5/25/16	Per cent trees dead 5/26/16	Per cent trees dead 4/4/17
March 21	CS_2 1-100	wet	60	8	100	62.5	75
	CS_2 1-100	wet	60	8	100	62.5	87.5
	CS_2 1½-100	wet	60	8	100	37.5	75
	CS_2 1½-100	dry	60	8	94.8	30	87.5
	Check	-------	----	8	100	25	62.5

The results obtained on the peach also show that carbon bisulphide will not entirely control San Jose scale when used at the rate of 1½ to 100. However, these results are much better than those obtained upon the apple which is probably due to the fact that most of the heavily infested peach trees died, which made it impossible to get as good a count. The peaches that lived were not so heavily infested.

TABLE 12.—PEACHES TREATED IN 1917

Date 1917	Treatment	Condition of trees	Length of treatment, min.	No. trees treated	Per cent scale dead 4/20/17
April 9	CS_2 1½-100	wet	60	4	100
	CS_2 1½-100	dry	60	4	100
	Check	-------	----	6	50

No live scale could be found upon the peach trees treated which was probably due to the fact that as a result of the treatment practically all of the young tender growth, which was the most heavily infested part of the trees, had died.

It will also be noticed that a larger per cent of the plants treated wet died, both at the end of the second month and at the end of the first year. However, the difference was not very great. With hydrocyanic-acid gas more of the plants treated dry died. It may be that carbon bisulphide has an altogether different physiological effect upon the plant, especially in the presence of moisture. A larger percentage of the scale on the trees treated wet were killed which seems to further indicate that carbon bisulphide used in the presence of moisture is more active.

Owing to the fact that carbon bisulphide did not in any case completely control the San Jose scale upon apple trees, and in only five out of six cases upon the peach, and since the percentage of injury to the plants was very great, its use as a fumigating material upon nursery stock should be discouraged.

LIME-SULPHUR FIRST USED

On page six, under "Control in the Orchard," a discussion of the first use of lime-sulphur for the control of insects is given.

F. A. Sirrine of New York Agricultural Experiment Station was probably the first to dip nursery stock for the control of San Jose scale. He dipped some nursery stock in 1894 on Long Island with a whale-oil soap preparation. Lime-sulphur was probably first used as a dip for nursery stock for the control of the scale by Professor C. V. Close of the Deleware Experiment Station in 1903.

Used up to present time.—Since 1894 a large number of experiments have been made with lime-sulphur as a tree dip for the control of San Jose scale but none have been, on the whole, entirely successful. In some cases the scale was controlled but the most serious objection to using it was the fact that in nearly every case the plants were injured to a greater or less extent. Although lime-sulphur is used almost altogether for controlling San Jose scale on old trees, it has never proven to be a practical success for dipping nursery stock.

Methods for using.—When lime-sulphur is used upon nursery stock as a spray for the control of San Jose scale, it is during the dormant season while the trees are still in the nursery row. It is applied at the usual rate, the same as recommended for mature trees, 1 to 7, and is put on with a spraying machine, either hand or power. Most large nurseries have especially constructed spraying machines which are built so as to be easily gotten between nursery rows.

When lime-sulphur or any other material is used for dipping nursery stock a vat is constructed or a trough made which is large enough to hold sufficient liquid to immerse an entire tree.

Chemical composition of lime-sulphur.—Lime-sulphur is made by boiling in water slaked rock lime containing not less than 95 per cent calcium oxide and flowers of sulphur. A very complicated chemical reaction takes place when lime and sulphur are boiled together in water. The sulphur (S) combines with the calcium (Ca) in the lime (CaO), in varying amounts, with the result that two compounds are formed—calcium tetrasulphide (CaS_4), containing 76 per cent of sulphur. Also a small quantity of thiosulphate (CaS_2O_3) is formed. These compounds formed are soluble in water and it is to them that the insecticidal value of the mixture is due. The higher the percentage of pentasulphide, the more effective is the mixture. In making the lime-sulphur solution it is necessary to boil it for an hour in order to form a complete chemical union of the lime and sulphur. Two parts of sulphur combine with one part of lime and in making the solution, twice as much sulphur as lime should be used.

RESULTS OF EXPERIMENTS WITH LIME-SULPHUR

As the lime-sulphur wash has become the most standard spray for the control of San Jose scale on infested fruit trees, the writer saw no reason why it should not be used to dip infested nursery stock.

Object.—The object in using lime-sulphur was to determine definitely, if possible, its exact efficiency for killing scale on nursery stock and its injurious effects, if any, upon the plants. Lime-sulphur is the cheapest material used in the control of San Jose scale and as no fumes are produced, it is less dangerous to use than hydrocyanic-acid gas or carbon bisulphide.

Procedure.—First a water tight wooden V-shaped trough was made, 9 feet long and 8 inches deep. This trough held with ease 8 gallons of the solution. The number of trees to be dipped were divided into four sets.

In the first set the tops and trunk, down to the roots only, were dipped and those trees dipped in 1916 and 1920 were immersed and immediately removed, while those dipped in 1917 were left immersed for five minutes. With the second set of trees the tops and roots both were dipped. With the first two sets lime-sulphur was used at the rate of 1 gallon to 9 gallons of water. The third and fourth sets were treated exactly as the first two except the lime sulphur was used at the rate of 1 gallon to 7 gallons of water.

After the trees had been dipped they were allowed to drain for a few minutes, then set out.

Effect of lime-sulphur upon San Jose scale.—As shown by the following table, forty apple trees, heavily infested with San Jose scale, were dipped in the lime-sulphur solution.

Table 13.—Apples Treated in 1916

Date 1916	Insecticide	Parts treated trees	Length of treatment, min.	No. trees treated	Per cent scale dead 5/25/16	Per cent trees dead 5/26/16	4/4/17
March 21	L. S. 1-9	tops	inst.	10	100	20	50
	L. S. 1-9	t. & r.*	inst.	10	100	30	70
	L. S. 1-7	tops	inst.	10	99.6	10	70
	L. S. 1-7	t. & r.*	inst.	10	93.6	30	50
	Check	--------	--------	20	38.9	0	60

*Both tops and roots dipped.

These results show that lime-sulphur will, to a very large extent, control San Jose scale on nursery stock but that the control may not be complete. Every tree was thoroly dipped, care being taken that every branch and twig was completely wet to the top, and the writer is convinced that none of the insects escaped immersion. Also a count of the scale was made from every tree and as shown by the results a very small percentage was alive a month after treatment. So far as the strength of the solution is concerned, the weaker gave the best results; however, there is very little difference in the strength of the two solutions used and the fact that the weaker solution gave the better results if of little significance.

In order to verify the above results, the following trees were treated in 1917 with lime-sulphur at a strength of 1-7.

TABLE 14.—APPLES TREATED IN 1917

Date 1917	Insecticide	Parts treated	Length of treatment, min.	No. trees treated	Per cent scale dead 4/20/1917
April 9	L. S. 1-7	tops	5	6	100
	L. S. 1-7	t. & r.	5	6	100
	Check	-------	5	4	75

In 1920 besides using commercial lime-sulphur in which to dip the trees, soluable sulphur, dry lime-sulphur and barium tetrichloride sulphide were used. The last three named compounds have been placed on the market and are sold as scale remedies. The following table shows the results obtained in 1920 with these different materials on scaly apple trees.

TABLE 15.—APPLES TREATED IN 1920

Date 1920	Treatment	Parts treated	Length of treatment,	No. of trees treated	Per cent scale dead 3/20/20	Per cent trees dead 11/18/20
March 27	1 gal. lime-sulphur to 9 gal. H_2O	t. & r.	inst.	34	96.62	91.1
March 27	1 gal. lime sulphur to 9 gal. H_2O	tops	inst.	34	99.66	44.1
March 27	1 lb. soluble sulphur to 4 gal. H_2O	tops	inst.	34	97.34	52.9
March 24	12 lbs. dry lime sulphur to 50 gal. H_2O	tops	inst.	34	100	50
March 25	14 lb. Barium tetrichloride sulphide to 50 gal. H_2O	tops	inst.	34	98.53	67.6
	Check	-------	-------	68	76	94.2

Of the above materials used dry lime-sulphur used at the rate of 12 pounds to 50 gallons of water gave the best results.

TABLE 16.—PEACHES TREATED IN 1916

Date 1916	Insecticide	Parts treated of trees	Length of treatment min.	No. trees treated	Per cent scale dead 5/4/16	Per cent trees dead 5/26/16	Per cent trees dead 4/4/17
March 21	L. S. 1-9	tops	inst.	4	100	25	25
	L. S. 1-9	t. & r.	inst.	4	100	25	25
	L. S. 1-7	tops	inst.	4	94.3	12.5	100
	L. S. 1-7	t. & r.	inst.	4	100	12.5	100
	Check	-------	-------	8	100	25	62.5

Practically the same results were obtained upon the peach in 1916 as upon apple.

TABLE 17.—PEACHES TREATED IN 1917

Date 1917	Insecticide	Parts treated	Length of treatment, min.	No. trees treated	Per cent scale dead 4/20/17
May 4	L. S. 1-7	tops	5	9	100
	L. S. 1-7	t. & r.	5	9	100
	Check	-------	--	6	50

As with the apple, no live scale could be found.

TABLE 18.—PEACHES TREATED IN 1920

Date 1920	Treatment	Parts treated	Length of treatment	No. of trees treated	Per cent scale dead 3/20/20	Per cent trees dead 11/15/20
March 27	1 gal. lime-sulphur to 9 gal. H_2O	t. & r.	inst.	34	99.66	44.1
March 27	1 gal. lime-sulphur to 9 gal. H_2O	tops	inst.	5	100	0
March 27	1 lb. soluble sulphur to 4 gal. H_2O	tops	inst.	5	100	100
March 24	12 lbs. dry lime-surphur to 50 gal. H_2O	tops	inst.	5	100	100
March 25	14 lbs. barium tetrichloride sulphide to 5 gal. H_2O	tops	inst.	5	100	80
	Check	-------	-------	10	86.67	100

Each treatment killed 100 per cent of the scale, except the first which killed 99.66 per cent.

TABLE 19.—PEARS TREATED IN 1920

Date 1920	Treatment	Parts treated	Length of treat-ment	No. of trees treated	Per cent scale dead 3/20/20	Per cent trees dead 11/15/20
March 27	1 gal. lime-sulphur to 9 gal. H_2O	t. & r.	inst.	2	100	100
March 27	1 gal. lime-sulphur to 9 gal. H_2O	tops	inst.	2	100	0
March 27	1 lb. soluble sulphur to 9 gal. H_2O	tops	inst.	2	100	0
March 24	12 lbs. dry lime-sulphur to 50 gal. H_2O	tops	inst.	2	100	100
March 25	14 lbs. barium tetrichloride sulphide to 50 gal. H_2O	tops	inst.	2	90	0
	Check	-------	-------	4	74.68	0

All gave good results except the barium tetrichloride sulphide which killed only 90 per cent of the scale.

TABLE 20.—PLUMS TREATED IN 1917

Date 1917	Insect-icide	Parts treated	Length of treatment, min.	No. trees treated	Per cent scale dead 4/20/17
April 4	L. S. 1-7	tops	5	1	100
	L. S. 1-7	t. & r.	5	1	100
	Check	-------	--	1	100

The scale on the treated trees were all dead..

The lime-sulphur solution used at both strengths caused considerable injury. There was not a great deal of difference in the strength of the two solutions used and some authorities claim that lime-sulphur used at the rate of 1 gallon lime-sulphur to 9 gallons of water will give as good results as 1 gallon lime-sulphur to 7 gallons of water. At the end of the first two months and also at the end of the first year, a larger percentage of stock treated with the weaker, or 1-9 solution, was dead, which seems to indicate that nursery stock can stand a solution of lime-sulphur a little stronger than 1-9 without any additional injury.

Neither did the lime-sulphur have any effect upon the roots of the plants which were treated in 1915, for in only one case, the 1-9 solution where both roots and tops were dipped, was the percentage of dead plants greater than when tops only were dipped. Of these plants treated with the 1-7 solution, the percentage of dead was greater in the set treated tops only. In 1920 the results were different and the plants that were dipped both tops and roots suffered a much higher mortality than those dipped tops only. All of the plants treated with both the lime-sulphur and miscible oil were dipped instantaneously. If the plants had been allowed to remain in the solution for 5 or 10 minutes or longer there would have probably been a greater difference in the results obtained.

The 1-9 solution gave better results in controlling the scale than the 1-7 solution, so taking everything into consideration it seems that just as good results could be obtained by using a 1-9 solution upon nursery stock for the control of scale, as a 1-7 solution. However, owing to the fact that none of the sulphur compounds killed all the scale and that considerable injury may result from their use upon young plants it seems advisable according to these experiments, to discourage the use of them as a dip.

MISCIBLE OIL FIRST USED

In a paper which appeared in Marseilles, France in 1763, petroleum, turpentine and other oils were recommended for killing plant lice. In this country turpentine mixed with earth and water was used to destroy worms in trees as early as 1835 and in 1865 kerosene was recommended for destroying scale on orange trees and was successfully applied to oleander, sago-palm, acacia and lemon trees. The oil was applied by means of a feather. In June 1866 kerosene was recommended, in Gardener's Monthly, for destroying all insect life. Later it was found that kerosene and other oils mixed better with water if a soap was added and the material could be applied with a syringe. It is not definitely known who made the first kerosene emulsion but about 1875 kerosene mixed with soap was first used.

Use up to present time.—Since 1875 many different mixtures containing miscible oils have been recommended for the destruction of both chewing and sucking insects, particularly the latter. Petroleum oils and soap form the basis of many patented miscible oil solutions which can be purchased on the market today. The miscible oils kill the insect by contact. The oil has great penetrating ability and probably kills the insect by preventing the assimilation of oxygen in the tissues.

The following are some of the most common and most widely used of the miscible oil insecticides.

Kerosene	2 gallons
Soap	½ pound
Water	1 gallon

Dissolve the soap in hot water, remove from fire and while still hot add the kerosene. Th emixture is thoroly agitated for five or ten minutes or until it becomes a creamy mass. Crude oil can be substituted for the kerosene. For a dormant spray one part of mixture is used to five or seven parts of water.

Distilate Emulsion

Distillate (28° Baume)	20 gallons
Whale oil soap	20 pounds
Water	12 gallons

Dissolve the whale oil soap in the water, which should be heated to the boiling point, add the distillate and agitate thoroly while the solution is hot. For dormant use, add 20 gallons of water to each gallon of stock emulsion.

Method of using.—The miscible oils may be used upon all types of sucking insects and also upon the chewing insects where it is desirable to kill them with a contact spray. The best results are obtained by using a spraying machine when treating trees in the field, either a power or hand pump, and give the trees a thoro spraying. When used for scale insects it must be applied during the dormant season. It may be used as a dormant spray upon nursery stock, but more generally when nursery stock is treated for scale with a miscible oil, a tank is constructed, the tank filled with the oil at the desired strength, and the trees dipped. It is the general belief that the oil is not good for the roots of a plant and the tops only are dipped.

Chemical composition of miscible oil.—The alkali in the soap or other emulsifier reacts upon the oil in such a way as to cause it to break up and become miscible in water. The commercial preparations are presumably composed of different types of oils treated in different ways and are protected by United States patents.

RESULTS OF EXPERIMENTS WITH MISCIBLE OIL

Owing to the fact that miscible oils are used to some extent in controlling San Jose scale upon fruit trees and, that in some states nurserymen are allowed to use it instead of hydrocyanic-acid gas upon nursery stock, an effort was made to determine its efficiency for controlling the scale, Some of the nurserymen who use a miscible oil to dip their stock say that it controls the scale just as well, if not better, than hydrocyanic-acid gas; that it is not so costly, and that there is less danger of injury to the tree. Also, like lime-sulphur, it is non-poisonous.

Procedure.—The larger nurserymen who make a practice of dipping their stock, usually construct a large cistern-shaped vat of concrete or use a large tank which they fill with the solution and in which very large trees can be dipped. In this work the same trough was used as with the lime-sulphur and in every detail the methods of procedure were the same with the exception of the solution. With the first two sets of trees treated, 1 gallon of oil was used to 15 gallons of water; with the third and fourth sets, 1 gallon of oil to 13 gallons of water was used.

Effect of miscible oil upon San Jose scale on apple.—The following table shows the results obtained by using miscible oil upon San Jose scale on apple trees, at the strength of 1 gallon to 15 gallons of water, and 1 gallon to 13 gallons of water.

TABLE 21.—APPLES TREATED IN 1916

Date 1916	Insecticide	Parts treated	Length of treatment min.	No. trees treated	Per cent scale dead 5/14-25/16	Per cent trees dead 5/26/16	Per cent trees dead 4/4/17
March 21	Mis. Oil 1-15	top	inst.	10	100	10	50
	Mis. Oil 1-15	t. & r.	inst.	10	100	0	40
	Mis. Oil 1-13	top	inst.	10	100	10	50
	Mis. Oil 1-13	t. & r.	inst.	10	100	20	50
	Check	--------	--------	20	38.9	0	60

Each tree was very carefully examined and no live scale whatever could be found, and the control seemed to be complete.

TABLE 22.—APPLES TREATED IN 1917

Date 1917	Insecticide	Parts treated	Length of treatment, min.	No. trees treated	Per cent scale dead 4/20/17
April 9	Mis. Oil 1-12	top	5	5	100
	Mis. Oil 1-12	t. & r.	5	5	100
	Check	--------	--	4	75

No live scale could be found when examined.

TABLE 23.—APPLES TREATED IN 1920

Date 1920	Insecticide	Parts treated	Length of treatment	No. of trees treated	Per cent scale dead 3/20/20	Per cent trees dead 11/15/20
March 26	1 gal. Mis. Oil to 15 gal. H_2O	t. & r.	inst.	34	100	88.2
March 26	1 gal. Mis. Oil to 15 gal. H_2O	tops	inst.	34	100	73.5
March 27	½ pt. Lemon Oil, 6¼ gal. H_2O and ½ lb. soap	tops	inst.	34	84.20	76.4
	Check	--------	--------	68	76	94.2

The lemon oil gave very poor results.

TABLE 24.—PEARS TREATED IN 1920

Date	Insecticide	Parts treated	Length of treatment	No. of trees treated	Per cent scale dead 3/20/20	Per cent trees dead 11/15/20
March 26	1 gal. Mis. Oil to 15 gal. H_2O	t. & r.	inst.	2	100	100
March 26	1 gal. Mis. Oil to 15 gal. H_2O	tops	inst.	2	100	100
March 27	½ pt. Lemon Oil, 6½ gal. H_2O and ½ lb. soap	tops	inst.	2	100	50
	Check	-------	-------	4	74.68	0

All treatments gave good results.

TABLE 25.—PEACHES TREATED IN 1916

Date 1916	Insecticide	Parts treated	Length of treatment min.	No. trees treated	Per cent scale dead 5/14-25/16	Per cent trees dead 5/26/16	4/4/17
March 21	Mis. Oil 1-15	top	inst.	4	100	0	0
	Mis. Oil 1-15	t. & r.	inst.	4	100	37.5	37.5
	Mis. Oil 1-12	top	inst.	4	99.3	25	25
	Mis. Oil 1-12	t. & r.	inst.	4	100	25	62.5
	Check	-------	-------	8	100	25	62.5

All of the above treatments proved effective with the exception of one, the 1-12, tops only, and the control in this case was 99.3 per cent. However, this is enough to reinfest the tree.

TABLE 26.—PEACHES TREATED IN 1917

Date 1917	Insecticide	Parts treated	Length of treatment, min.	No. trees treated	Per cent scale dead 4/20/17
April 9	Mis. Oil 1-12	top	5	9	100
	Mis. Oil 1-12	t. & r.	5	9	100
	Check	-------	..	6	60

No live scale could be found.

TABLE 27.—PEACHES TREATED IN 1920

Date 1920	Insecticide	Parts treated	Length of treat-ment, min.	No. of trees treated	Per cent scale dead 3/20/20	Per cent trees dead 11/15/20
March 26	1 gal. Mis. Oil to 15 gal. H_2O	t. & r.	5	5	100	60
March 26	1 gal. Mis. Oil to 15 gal. H_2O	tops	5	5	100	40
March 27	½ pt. Lemon Oil, 6¼ gal. H_2O and ½ lb. soap	tops	5	5	60	80
	Check	--------	.	10	85.67	100

The foregoing tables show that miscible oil does not injure nursery stock to any great extent; however, as compared with the check, some injury results from its use. Probably some time is required before the injury shows up to any great extent. At the end of the first two months the per cent of dead plants was not so great where the tops only were treated, as in the case of the checks. At the end of a year, however, there was about three times as many of the plants, which were treated tops only, dead as in the case of the check. Those plants which were dipped both tops and roots showed a higher percentage of death than those dipped tops only. So it seems that it is not advisable to dip the roots of plants in miscible oil.

In comparing the two strengths of miscible oil used, the 1 gallon to 12 gallons of water, caused a much greater percentage of injury than the weaker strength of 1 gallon of the oil to 15 gallons of water.

As to the control of San Jose scale, the miscible oil gave excellent results. Both strengths controlled the scale upon the apples. Upon the peach the results were as good with the exception of those treated, tops only, with the 1-12 strength and in this case 99.3 per cent of the scale was killed.

Taken as a whole, the miscible oil injured the plants less and controlled the San Jose scale better than any of the other materials used.

As the tables show the lemon oil which was used in 1920 gave very poor results. Lemon oil is used to some extent by florists to spray green house plants which are infested with scale insects, however it seems to be of little value in controlling San Jose scale.

NICOTINE SULPHATE AS A SPRAY

In addition to all of the other materials used in 1920 nicotine sulphate, a tobacco extract, was tried. It is a sulphate of nicotine and therefore an acid material. It contains 40 per cent nioctine and is used as a contact spray for soft bodied insects like the plant lice. It is usually used at the rate of one gallon of nicotine sulphate to about 800 gallons of water. In using it as a dip for San Jose scale on dormant trees it was used at the rate of one gallon of nicotine sulphate to 100 gallons of water. The following tables show the results obtained.

TABLE 28.—APPLES TREATED IN 1920

Date 1920	Treatment	Parts treated	Length of treatment min.	No. of trees treated	Per cent scale dead 3/20/20	Per cent trees dead 11/15/20
March 27	1 gal. Nicotine sulphate to	tops	inst.	34	64.74	91.1
	Check	....	....	68	76	94.2

TABLE 29.—PEACHES TREATED IN 1920

Date 1920	Treatment	Parts treated	Length of treatment min.	No. of trees treated	Per cent scale dead 3/20/20	Per cent trees dead 11/15/20
March 27	1 gal. Nicotine sulphate to 100 gal. H_2O	tops	inst.	5	100	80
	Check	....	....	10	85.67	100

TABLE 30.—PEARS TREATED IN 1920

Date 1920	Treatment	Parts treated	Length of treatment min.	No. of trees treated	Per cent scale dead 3/20/20	Per cent trees dead 11/15/20
March 27	1 gal. Nicotine sulphate to 100 gal. H_2O	tops	inst.	2	100	100
	Check	....	....	4	74.68	0

Nicotine sulphate seemed to have killed all the scale on the peach and pear but on the apples it gave very poor results. It also caused considerable injury to the plants treated. Evidently it should not be used as a dip in controlling San Jose scale on nursery stock.

SUMMARY

1. Hydrocyanic-acid gas did not in every case completely control the San Jose scale. However, the gas used at a strength of 1-1-3 gave better results than the weaker strength of ½-½-1½. The 1-1-3 strength gave as good results as the 2-2-6 strength. Sodium cyanide used at the strength of 1-1½-3 killed 100 per cent of the scale.

2. Hydrocyanic-acid gas was more effective when used upon dry plants than upon wet. A larger percentage of the scale was killed.

3. All strengths of the hydrocyanic-acid gas caused more or less injury to the plants. The stronger it was used, the more injury it caused.

4. The 1-1-3 formula should always be used in fumigating nursery stock, and the stock should be dry. There may be greater danger of injury to the plants, but the scale will be more completely controlled, and this is the most important factor.

5. Carbon bisulphide did not control the scale and it caused a very high percentage of injury. Its use as a fumigating material for the control of San Jose scale on nursery stock should be discouraged.

6. Lime-sulphur used at 1-9 and 1-7 strengths gave fairly good results in controlling the scale. The 1-9 solution gave perfect results on pears and plums.

7. The sulphur dips injured the plants to some extent. The plants dipped both tops and roots showed more injury than those dipped tops only.

8. The miscible oil gave the best results, 100 per cent of the scale being controlled in every case but one and in this case the control exceeded 99 per cent.

9. Miscible oil caused some injury to the plants. Those dipped tops and roots were injured most. When treating nursery stock with miscible oil the roots should not be dipped.

10. Lemon oil or nicotine sulphate should not be used as dips for controlling scale on nursery stock.

11. None of the materials used completely controlled the San Jose scale.

12. All scale-infested nursery stock should be burned or destroyed in some other way.

13. Nursery stock which has been subjected to infestation, but is not infested should be treated before being placed on the market.

14. The best results should be expected by treating the stock with hydrocyanic-acid gas 1-1-3, or with miscible oil at the strength of 1-12 or 1-15, tops only.

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COLUMBIA, MISSOURI

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PLANT INSPECTION IN MISSOURI

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Plant inspection work has been carried on in a systematic manner in Missouri since 1913, and it is the object of this report to give a brief summary of the work done since that time and the results accomplished.

The inspection of nurseries in particular has a direct bearing upon the fruit industry, for it is thru the distribution of nursery stock that our most dangerous insect pests and plant diseases have been scattered from one fruit-growing community to another. Unfortunately, it has been only during the last few years that the full value of a systematic annual inspection of nurseries and orchards has been appreciated, with the result that prior to 1913 only those nurseries, which shipped stock, received annual inspection. In the meantime many very serious insect pests and plant diseases have been introduced into the fruit-growing sections of the state. Many of these pests and diseases like the San Jose Scale, crown gall and hairy

Fig. 1.—A good grape nursery in southwest Missouri

root first gained their admission to Missouri on nursery stock. The tax paid to insect pests and diseases by the Missouri fruit growers in the last fifty years has amounted to hundreds of millions of dollars. Much of this loss could have been prevented had the real value of inspection work and the control of insects and diseases been realized sooner.

Several of the more prominent nurserymen and fruit growers of Missouri did realize the value of inspection work and for a number of years before Missouri had an inspection service they secured the assistance of the entomologists of the Agricultural Experiment Station and had their nurseries and orchards inspected annually. However, due to the expense, only the larger and more prosperous nurserymen and orchardists felt that they could afford to have their premises inspected each year.

The need of a good inspection service for Missouri, which would be state wide, and which would reach out to the little nursery men and orchardists as well as the large ones, became so apparent that in 1913 the State Legislature passed a Nursery Inspection Law providing for the inspection of plants by the Missouri Agricultural Experiment Station. This law was approved by the Governor March 27, 1913.

The purpose of the Law is to prevent the further introduction of San Jose scale and other dangerously injurious insects and plant diseases, and to suppress as far as possible those pests which may have secured a foothold in this state. This Law also provides fully for the most careful inspection of suspected plants and for the destruction of badly diseased plants, the distribution of which might result in serious consequences to the farmers and fruit growers of Missouri.

The Nursery Inspection Law further provides that it shall be the duty of the Agricultural Experiment Station at Columbia to seek out, suppress and eradicate San Jose scale and other dangerous insect pests and plant diseases affecting the agricultural and horticultural interests of the State of Missouri. The Agricultural Experiment Station shall make necessary regulations and shall be vested with all the powers necessary to carry into effect the provisions of this Act.

Section 2 of the Law authorizes the official inspectors to enter any grounds or other premises for inspection and eradication of insects and diseases. It further authorizes the Agricultural Experiment Station to carry on demonstrations and experiments dealing with insect control and to give information on the control of insects and plant diseases by lectures and printed literature.

Section 3 of the Law gives the Agricultural Experiment Station authority to inspect from time to time nurseries, orchards, fruit plantations or other property and if dangerous insect pests or plant diseases are found it shall recommend the method of treatment.

Section 4 of the Law provides that each person or corporation in the state engaged in growing nursery stock for distribution shall notify the office of the Plant Inspection Service on or before the first day of July of each year and make application for the inspection of their nursery stock. The Plant Inspection Service must inspect the stock before September 15. Each individual or corporation importing nursery stock from a foreign country must notify the Plant Inspection Service upon the arrival of the stock.

The Plant Inspection Service shall issue to each nurseryman a certificate of inspection providing the stock has been found free of dangerous insect pests and plant diseases. The certificate is good for one year providing a fee of $5 has been received for the certificate plus the actual necessary expenses incurred in making the inspection. All shipments of nursery stock originating in Missouri must have attached to it a certificate of inspection from the Plant Inspection Service of Missouri. All shipments of nursery stock originating outside and coming into Missouri must have attached to it a certificate of inspection satisfactory to the Missouri Plant Inspection Service. Annually every nursery or firm outside Missouri shipping nursery stock into Missouri must file with the Missouri Plant Inspection Service a valid certificate of inspection issued by a state or government inspector showing that said stock has been inspected and found free from all dangerous insect pests and plant diseases, together with a statement under oath that no stock will be shipped into Missouri that has not been inspected and certified.

Annually every agent or authorized representative of any nursery or dealer must file with the Missouri Plant Inspection Service a statement under oath that he will offer for sale no stock which has not been duly inspected and certified, together with a copy of the certificate of and proper credentials from the nurseryman or dealer represented.

Annually, each dealer, person or firm engaged in the sale and delivery of nursery stock in Missouri and who is not the authorized representative of any nurseryman must file in the office of the Missouri Plant Inspection Service a statement under oath that he will handle only stock which has been officially inspected and certified. The statement must contain the names of the nurserymen or firms from which stock is obtained. He must also obtain a dealer's certificate from the Plant Inspection Service for which a fee of $5 must be paid and which is good for one year beginning July 1 of each year. This certificate may be attached to shipments of nursery stock.

Section 5 requires that all shipments of nursery stock must be plainly labeled on the outside with the name of the consignor and consignee and a brief statement of the contents and a valid certificate of inspection. It is unlawful to deliver shipments of nursery stock in Missouri that are not so labeled.

Section 6 provides that any owner of an orchard or fruit plantation or dealer in plant products can request the Plant Inspection Service to inspect the same, and as soon as convenient the Plant Inspection Service must make the inspection and issue a certificate to the facts disclosed by the inspection.

Section 7 provides the penalty for violating the Nursery Inspection Act. The penalty of violating the Nursery Inspection Act is a fine of not less than $25 nor more than $100 for each offense, together with the cost of procedure. The prosecuting attorney shall prosecute violators of the act.

Section 8 defines the terms "nursery stock," "dangerous insect pests" and "plant diseases."

Section 9 provides for the enforcement of the Nursery Inspection Act which is placed under the supervision of the director of the Agricultural Experiment Station and he is empowered to appoint a chief inspector and such additional assistants as may be necessary to execute the provisions of the Act.

Under the provision of the Nursery Inspection Law, Dr. Leonard Haseman, Entomologist of the Agricultural Experiment Station, was appointed Chief Inspector and since 1913 the provisions of the law have been carried out under his direction.

Every state in the Union maintains a nursery inspection service of some type and the nursery inspection service of Missouri closely cooperates with the officials of the different states especially as regards the shipping of nursery stock to and from those states and Missouri.

The Federal Government also maintains a large inspection service

Fig. 2.—Inspecting evergreens in a Missouri nursery

which is under the control of the Federal Horticultural Board. The Federal Board regulates the importation of all kinds of plants, seeds, etc., including nursery stock from foreign countries, and also makes rules and regulations when necessary regarding interstate shipping of nursery stock, etc.

The Missouri Plant Inspection Service cooperates in every way possible with the Federal Board in furthering the eradication of dangerous insect pests and plant diseases and in preventing the introduction of new ones. Every year, Missouri nurserymen and florists import large quantities of nursery stock from foreign countries, especially France, Belgium and Holland. The Federal Horticultural Board requires that all imported stock be inspected upon arriving at its point of destination. Officials of the Missouri Plant Inspection Service inspect all of this foreign stock which comes into Missouri.

PLANT INSPECTION, 1913

As soon as the Plant Inspection Law was passed and approved by the Governor, the director of the Agricultural Experiment Station appointed the Chief Inspector and plans were at once begun for carrying out the requirements of the Law.

Most of the inspection for 1913 was made during July and August by Dr. Leonard Haseman, Chief Inspector, and T. J. Talbert, Assistant in Entomology, and B. Szymoniak, Assistant in Horticulture, who had been deputized to assist with the work.

During the months July, August and September, 1913, 125 nurseries were inspected, of which 114 were certified as being free from injurious insect pests and plant diseases. Twenty-three nurseries were found to be infested with San Jose scale. A total of 3,000 acres of nursery stock was

FIG. 3.—Good two-year-old apples of which hundreds of acres are grown in Missouri every year

inspected; located in 44 different counties. Also during the year 500 cases of imported stock containing over 500,000 plants were inspected.

Inspection Certificates to the number of 114 were issued by the Plant Inspection Service and 78 certificates were issued to dealers in nursery stock. One hundred and nineteen permits were issued to growers in other states who desired to ship nursery stock into Missouri and 377 permits were issued to agents or representatives of nurseries who desired to sell stock in Missouri.

As previously stated, twenty-three nurseries were found infested with San Jose scale and steps were immediately taken to clean up these infestations. Also, in connection with the nursery inspection work, a considerable acreage of orchard was inspected. Every attempt possible was made to determine whether or not the San Jose scale was present in orchards dangerously near nurseries. In many cases it was found near the nursery blocks and when in dangerous proximity the nurseryman was required to take due precaution in preventing the spread from the orchards to his nursery stock. Owners of such orchards were given orders to clean them up and in most cases steps were taken at once to destroy infested trees and shrubs.

Due to the fact that 23 nurseries and a large number of orchards were found infested with San Jose scale an educational campaign, as provided for in the Nursery Inspection Law, was inaugurated in the fall of 1913. Where a nursery was found infested with scale the nurseryman was required to destroy all infested plants including trees and shrubs and to treat all stock subject to infestation with hydrocyanic-acid gas.

Also scale-infested orchards were selected at Sikeston, Boonville, Willard, Pierce City, Jackson, Hannibal and Alexandria and during the fall of 1913 and early spring of 1914 spraying demonstrations were held at these places for the control of the scale. In this work no effort was made to spray large orchards in each locality but only a portion of an orchard. Just enough spraying was done to show the fruit growers who were not familiar with scale control just how it should be done. At these spraying demonstrations, meetings were held at which methods of controlling insects and diseases were described. Also the best methods of planting, pruning, cultivating, selecting the site and other practical subjects of orchard management were given consideration. The results obtained from these demonstrations were quite satisfactory and led to the purchase by many fruit growers of sprayers and spraying material and the production of cleaner and better fruit. The results of this work are given in detail in Missouri Experiment Station Bulletin 132, "The Control of San Jose Scale in Missouri."

The results of the first year's work of nursery and orchard inspection showed clearly that a number of the nurserymen and many fruit growers faced the problem of eradicating that most serious of nursery and orchard pests, the San Jose scale, and also that the Plant Inspection Service had a big task before it in helping in this work of keeping Missouri orchards free from injurious pests and diseases in the future.

PLANT INSPECTION 1914-1915

During the year 1914-15 the inspection work was done by Dr. Leonard Haseman, Chief Inspector and Mr. T. J. Talbert, Deputy Inspector. A total of 135 nurseries were inspected of which 113 were certified. The acreage of nursery stock in Missouri in 1914-15 was 2551 located in 44 different counties. Five hundred and forty-nine cases of foreign stock received in 13 different counties were inspected. These 549 cases contained nearly 600,000 plants. One hundred and thirteen certificates of nursery inspection were issued; sixty-four dealers certificates, ninety-four growers permits and 249 agents permits.

Eleven more nurseries were inspected in 1914 than in 1913. These nurseries existed in 1913 but due to the fact that 1913 was the first time that a systematic inspection was ever attempted it was almost impossible to locate every nursery in the State. These nurseries which were located and inspected for the first time in 1914 were small ones and not widely known.

Also some of them were infested with San Jose scale. A total of twenty-three nurseries were found to be infested in 1913 while in 1914 the number infested was twenty-seven. Many of the nurseries which were found infested in 1913 had been thoroughly cleaned up but as a large percentage of the nurseries inspected for the first time in 1914 were found infested the total number of infested nurseries was higher than in 1913. As in 1913 the amount of foreign stock received in 1914-15 was large and a great deal of time was spent in inspecting it.

The results of the nursery inspection work in 1914-15 showed that the problem of eradicating the San Jose scale from the infested nurseries was indeed a great one and plans were made to push with increased vigor the work of eradication.

PLANT INSPECTION 1915-16

During the summer of 1915 the inspection work was done by A. H. Hollinger, Assistant in Entomology who was appointed to fill the vacancy caused by the resignation of Mr. Talbert, and by K. C. Sullivan and J. H. Shepherd who were appointed deputy inspectors for the summer. All these were under the direction of Dr. Haseman, chief inspector. The scope of the work was greatly enlarged in 1915 and a large acreage of orchards were inspected in practically every county of the state.

Of the 173 nurseries inspected in 1915-16, 161 were certified. Two thousand six hundred and two acres of nursery stock was inspected in forty-six different counties and 489 cases containing 325,106 foreign plants were inspected in fourteen different counties.

One hundred and sixteen nursery inspection certificattes; eighty-seven dealers certificates; 125 growers permits and 300 agents permits were issued by the Plant Inspection Service in 1915-16.

It will be noticed that in 1915-16, 173 nurseries were inspected as compared to 135 in 1914-15. This increase was due to the fact that many of the strawberry growers in Southwest Missouri who had exceedingly fine beds wished to sell and ship plants and in order to meet the requirements of the different states had their plant beds inspected.

FIG. 4.—Looking down the row of a block of seedling peaches. These are peaches ready to bud

Twenty-four nurseries of the 173 inspected were found to be infested with San Jose scale while in 1914 twenty-seven nurseries out of 136 inspected were infested. This reduction of scale-infested nurseries was due largely to the efforts of the Inspection Service and its ability to cooperate with the nurserymen in a just and fair manner. Altho the nursery and orchard inspection service has police power, at no time was it necessary to use this power in connection with the San Jose scale clean up work. The scale clean up work was conducted as an educational project and in every case the nurseryman was glad to do his part. Where a nursery was found to be infested with San Jose scale or any other dangerous pests or diseases, the owner was immediately told of the existing conditions and given instructions as how to proceed in order to bring about their eradication. Usually the nursery was visited the second time in the digging period and all infested stock was condemned and burned and the remainder treated either with hydrocyanic acid or a miscible oil dip, and as is shown, this work was very effective.

In addition to the regular nursery inspection work the Plant Inspection Service in 1915-16 for the first time did a large amount of orchard inspection. The inspection of permanent orchards is one of the most important projects of the Plant Inspection Service and until this time no definite information had ever been obtained as to the prevailance of dangerous insect pests and diseases in the orchards of Missouri. This was especially true with ref-

Fig. 5.—A lot of scale-infested nursery stock which was condemned by the Plant Inspection Service

erence to the San Jose scale. Before this time the San Jose scale had been found in a number of commercial orchards but no one knew just how generally it was scattered over the state. The object in making an inspection of the orchards in all sections of the state was to find out definitely just how great a foothold the more serious insect pests, especially San Jose scale, and plant diseases had obtained in Missouri. Therefore, during the year 1915-16, 118 orchards composing a total of 1,967 acres located in sixty-nine counties were visited by inspectors from the Plant Inspection Service and carefully examined.

Thirty-nine or practically a third of the orchards inspected were found to be infested with San Jose scale, some very bad, others very slightly. Whenever an orchard was found to be infested with San Jose scale or any other pest or disease, instructions were given regarding the eradication of the pest or diseases. It is a well known fact that an old orchard is an ideal place for such pests as the San Jose scale to breed from year to year and unless it is thoroughly cleaned up will serve as a source of infestation for an entire community and in the long run may cause a loss of thousands of dollars. In case an infested orchard was found near a nursery, additional emphasis was placed upon the necessity of cleaning up the premises. It is gratifying to state that in practically every case the fruit growers were more than willing to cooperate with the Plant Inspection Service in every way in order to get rid of dangerous pests and diseases. That most dangerous of orchard pests, the San Jose scale, is widely distributed over Missouri and the Plant Inspection Service has a gigantic task before it in cleaning up and preventing a further spread of this pest. A task which will require both a great deal of time and a great deal of money, but which in the end will amount to very little as compared to the returns which can be obtained from a clean and healthy orchard.

The results of the inspection work in 1915-16 showed very conclusively that the Missouri Plant Inspection Service was rendering a great service to the nurserymen and fruit growers of the State by locating and helping clean up infestations of dangerous insect pests and diseases.

PLANT INSPECTION 1916-17

During the year of 1916-17 the nursery inspection work was carried on by Dr. Leonard Haseman, chief inspector and C. V. Vinson and K. C. Sullivan, deputies. The work was conducted in the same manner as the year before, except very little orchard inspection work was done due to insufficient funds necessary for carrying on such work.

One hundred thirty nurseries were inspected located in forty-seven different counties of which 107 were certified. The total acreage of nursery stock growing in Missouri in 1916-17 was 2,860. Three hundred eighty-nine cases of imported stock containing 570,766 plants were inspected in eleven different counties. One hundred seven certificates of nursery inspection; sixty-seven dealers certificates; 101 growers permits and 182 agents permits were issued in 1916-17. Twenty-two nurseries were found to be infested with San Jose scale, being two less than in 1915-16.

The report for 1916-17 shows that the numbers of scale infested nurseries was gradually being decreased. The clean up work in 1916-17 was carried on as in 1915-16.

PLANT INSPECTION 1917-18

The work of the Plant Inspection Service was carried on in 1917-18 by Dr. Leonard Haseman, chief inspector and A. H. Hollinger and K. C. Sullivan, deputies.

One hundred twenty-three nurseries were inspected and 103 were certified. The nurseries inspected were located in forty-five different counties and included a total of 2,035 acres. Forty-four cases of imported stock containing 425,849 plants received in seven different counties were inspected. Fifteen nurseries were found infested with San Jose scale as compared to twenty-two in 1916-17. This noticeable decrease in scale-infested nurseries was due largely to the untiring efforts of the Plant Inspection Service.

Another noticeable fact was the decrease in acreage which was due largely to the war which caused a decrease in demand for nursery stock. When the demand became less the nurserymen naturally planted a smaller acreage. Also many of the Missouri nurserymen for patriotic reasons lessened their acreage of nursery stock and grew a large acreage of wheat and corn which was badly needed at that time.

PLANT INSPECTION 1918-19

During the year 1918-19 all of the nursery inspection work was done by Dr. Leonard Haseman and K. C. Sullivan with some assistance by T. J. Rosa, Jr., Help was very scarce and also the number of nurseries to be inspected was less than ever before, due largely to the war.

Ninety-six nurseries were inspected, of which number ninety were certified. A total of 1,313 acres located in forty different counties were inspected. One hundred twenty-seven cases of imported stock containing 314,631 plants were inspected in nine different counties. Ninety certificates of nursery inspection, thirty-five dealers certificates; 111 growers permits and ninety-two agents permits were issued.

The report of 1918-19 shows very conclusively the effect of the war upon the nursery business in Missouri in both the number of nurseries and the total acreage of stock. Due to the decrease in the demand for nursery stock and the scarcity of labor, many of the smaller nurseries closed down altogether and the larger ones cut down the acreage.

In 1918-19 only two nurseries were found to be infested with San Jose scale and those but slightly. In 1913 when the Missouri Plant Inspection Service began to function, twenty-three nurseries were found to be infested. Taking into consideration the fact that San Jose scale is about the hardest insect known to eradicate, the Inspection Service really feels it had accomplished a great deal of good in the short time which it had been working.

Up to this time the Missouri Plant Inspection Service had been maintained entirely by fees paid by the nurserymen. This source of income could be relied upon, but it was entirely inadequate to carry on the work of nursery and orchard inspection properly in the state. In 1917 the State Legislature, realizing the importance of the nursery and orchard inspection work, made an appropriation of $5,000 to be used in furthering the work. This appropriation, however, was not made available. In 1919 the State Legislature again made an appropriation for the Plant Inspection Service. This time the amount was $10,000 of which $2,000 was made available in 1919, thus partially placing the Plant Inspection Service on state support.

PLANT INSPECTION 1919-20

During the year 1919-20 the nursery and orchard inspection work was done by Dr. Leonard Haseman, chief inspector and K. C. Sullivan and S. R. McLane, deputies. Also a small amount of work was done by R. S. Springate. As was stated before $2,000 of the appropriation made by the State Legislature was made available for the work during 1919-20 with the result that a great deal more good was accomplished than ever before.

Ninety-three nurseries, located in forty different counties, were inspected, eighty of which were certified. A total of 1,469 acres of nursery stock was growing in 1919-20. Sixty-seven cases of foreign stock containing 442,000 plants were received in six different counties and inspected. Eighty nursery inspection certificates; twenty-three dealers certificates; 157 growers permits and 121 agents permits were issued.

During the year 1919-20 eight nurseries were found to be slightly infested with San Jose scale. In every case the nursery infested was in close proximity to a heavily infested orchard and as the season in 1919-20 was favorable for the growth and spread of the scale some of the near-by nurseries had become infested to some extent, but none seriously. As in previous years every precaution was taken to prevent its further spread and to eradicate it from the nurseries and the near-by orchards.

The method most generally used in eradicating and preventing the spread of San Jose scale on nursery stock and the one recommended by the Plant Inspection Service is to destroy all visibly infested stock and treat all other stock, subject to infestation, by either hydrocyanic acid gas or by dipping it in a miscible oil. The hydrocyanic acid gas treatment is more commonly used than the latter. In using this gas this method is followed:

One fluid ounce of sulphuric acid having a specific gravity of at least 1.83 is placed in an earthernware crock, wooden bucket, or tub; then 3 fluid ounces of water are added. In this mixture 1 ounce, by weight, of fused cyanide of potassium, 98-99 percent pure, is added. The above amounts are used for every 100 cubic feet of space. In fumigating tender growing plants, the above formula is too strong and has to be weakened. For dormant trees, mills, elevators and the like the 1-1-3 formula is recommended by both the United States Department of Agriculture and practically all of the state experiment stations.

In fumigating nursery stock an air tight box or house is necessary. The trees are placed in the box or house. The water and sulphuric acid are mixed in an earthern jar and the jar placed in the box or house. The potassium cyanide is then dropped in and the box or house closed just as quickly as possible. The hydrocyanic acid gas which is generated is deadly poisonous and the person doing the fumigating must be very careful not to breathe any of it. It requires about 45 minutes to fumigate nursery stock, although some authorities say that better results can be obtained by letting the stock remain an hour. At the end of this time the fumigating box or house is opened and the gas allowed to escape and in from 15 to 20 minutes the trees can be safely removed.

It is never advisible to fumigate trees while they are damp or wet. It is claimed that under such conditions the gas is more likely to injure the stock. However, the writer's experiments to date fail to corroborate this, though they do show that less scale is killed under those conditions.

Some states require by law that all nursery stock grown within its borders or shipped in from outside nurseries be fumigated, and, as a result, all of the larger nurseries in the United States have constructed special fumigating houses or boxes.

At the present time a form of sodium cyanide which is stronger than potassium cyanide is being substituted for the latter. Due to the fact that the sodium cyanide is stronger than the potassium cyanide a slight change has to be made in the formula, otherwise the method of using it is exactly the same. The formula recommended when using sodium cyanide is one ounce of sodium cyanide, 1½ ounces sulphuric acid and two ounces of water. Sodium cyanide is much cheaper than potassium cyanide and gives just as good results and is therefore coming into general use.

As previously stated, the use of a miscible oil for treating nursery stock which has been subject to infestation by San Jose scale is practiced to some extent by some nurserymen and good results have been obtained. In case a miscible oil is used, a tank or vat is constructed large enough to allow the dipping or complete emersion of the top of the trees to be treated. The oil is used at a strength of one gallon of the oil to twelve or fifteen gallons of water and the stock to be treated is completely emersed except the roots, immediately removed and allowed to drain and dry.

In 1915 a number of experiments were started at the Missouri Agricultural Experiment Station to determine the most practical, efficient and cheapest method to use in controlling scale on nursery stock with the least possible injury to the plants. The results of this work will appear in a separate publication.

Unfortunately only $2000 of the $10,000 appropriation made by the State Legislature was made available for use in 1919-20 and this was not made available until very late in the year. However, this sum made it possible for the inspection service to carry on its work to a much greater extent than would otherwise have been possible.

Due to the increase in price of railroad fares, hotel accommodations, labor etc., it costs the Inspection Service just about twice as much to do the same amount of work as it did four years ago. Thus it would have been practically impossible for the inspection service to have carried on its work without this additional help.

PLANT INSPECTION 1920

During the year 1920 the inspection work was done by Dr. Leonard Haseman, chief inspector and K. C. Sullivan, S. R. McLane and G. A. Tumbleson, deputies. Due to the fact that $5000 of the $10,000 state appropriation was made available the work of the Plant Inspection Service was enlarged. A very important phase of the work which is being carried on in addition to the nursery and orchard inspection is the inspection for the European Corn-borer, which will be discussed later.

The following 100 nurseries were inspected during the summer of 1920:

NURSERIES INSPECTED 1920-21

Aroma Plant Company. Seligman
Bennet. B. F., Seymour
Bellefontaine Cemetery, St. Louis
Birch, F. A., Neosho
Crumly Brothers, Monett
Calvary Cemetery, St. Louis
Cameron Nursery, Cameron
Case Nursery, Case
Chapman, W. C., Higbee
Clever Nursery Company, Clever
Crotsenburg, C. N., Carthage
Davis, E., Seligman
De Soto Nursery Co., De Soto
Dobbs, Earl S., Anderson
Elk Horn Nurseries, Noel
Ely, H. S. & Company, Neosho

Eastridge and Landis, Neosho
Ellisville Nursery, Ellisville
Farmers Nursery, Chillicothe
Fairview Nursery, Bethany
Fort, J. T. Nursery Co., Kansas City
Flowers, F. A., Carthage
Gibson's Ozark Nursery, Springfield
Golden City Nursery Co., Golden City
Howell County Nursery, West Plains
Hatzfeld, L. H., Goodman
Halava Nursery, Hillsborough
Hall, W. S., Hannibal
Hardy-Field Nursery & Seed Co., Kansas City
Hendricks J. O., Seligman
Hermann Grape Nursery, Hermann,
Jablonsky, A., Ovillete
Jones, Elva A., Anderson
Jenkins, H. W., Boonville
Kansas City Peony Gardens, Kansas City
Kaupp Floral Company, Nevada
Kelsey Nurseries, St. Joseph
Lamberth, O. H., Sarcoxie
Linn, F. B., Louisiana
Litson Nursery, Nevada
Ludwig, Henry, Pochontas
Luke's Nursery, Lowry City
Model Nursery, Poplar Bluff
May Brothers Nursery, Sedalia
McCurdy, J. F., Marshall
McCartney, E. W., Neosho
Morris, Miss Mary, Neosho
Murray Nurseries, Oregon
Norton, A. L., Clarksville
Neosho Nursery Co., Neosho
New Haven Nurseries, New Haven
Old Reliable Nursery, Kansas City
Ozark Nursery Co., Seligman
Osage County Nursery, Aud
Oronogo Flower Garden, Carterville
Park Floral Co., St. Joseph
Pasteau Nursery, St. Louis
Peyton Nursery, Boonville
Piedmont Nursery,, Piedmont
Pinehurst Floral Co., Pleasant Hill
Polster Nursery, Warrenton
Rausch, Charles, Monett
Ragan, O. P., Ridgeway
Rau Floral Co., St Joseph
Rhoeder Nurseries, Osceola
Reed, Homer, Louisiana
St. Louis Park Dept., St. Louis
St. Louis Water Dept., St. Louis
Sanders Nursery Co., St. Louis
Schnell, Henry, Glasgow
Schreier, A., Neosho
Seligman Plant Co., Seligman
Sedan & Mt. Grove Nursery Co., Mt. Grove
Swope Park Nurseries, Kansas City
Sommers Nursery, St. Joseph
Stanley Nursery, Campbell
Stark Bros. Nursery & Orchard Co., Louisiana
Southwest Golden Nurseries, Bolivar
Sunny Slope Seed Farm, Independence
Taiclett, F. A., Neosho
Teas Nursery, Carthage
Taos Nursery, Taos
Thuli, J. A. & Sons, Chamois
Vallenweider, C., Seymour
Valhalla Cemetery, St. Louis
Wiseman Nursery, Springfield
Wallace, R. F., Logan
Waldbart, A. & Sons, St. Louis
Westport Nursery Co., Kansas City
Watson, J. G., Seligman
Wallace Nursery, Farmington
Walker, Rolla, Neosho
Wayman, H. S. & Son Nursery, Princeton
Weber, H. J. & Sons Nur. Co., Nursery
Westover Nursery Co., St. Louis
Wild, Gilbert Nursery, Sarcoxie
Wild Bros. Nursery Co., Sarcoxie
Wilson John L., Anderson
Young C. & Sons Co., St. Louis, Mo.

Of the above list of nurseries nine were found to be slightly infested with San Jose Scale. The year 1919-20 was one of the most favorable years known in Missouri for the propogation and spread of San Jose Scale and in some of the nurseries it was found for the first time in 1920. Every nursery found infested is being reinspected at the time the stock is dug and every effort is being made to completely eradicate the San Jose scale from every nursery in Missouri.

In 1920-21 there was a total of 1681 acres of nursery stock growing in nurseries in forty-two different counties. The counties having the largest acreage were Newton, Lawrence, St. Louis, Pike, Buchanan and Franklin. There was practically 200 acres more of nursery stock growing in 1920-21 than in 1919-20. This seems to indicate that like a great many other industries the nursery and orchard industry in Missouri has entered upon a period of prosperity and that in the future a still larger amount of nursery stock will be grown and a greater acreage of fertile Missouri soil will be planted to orchards.

REPORT OF THE EUROPEAN CORN BORER INSPECTION WORK

During the summer of 1920 a careful search was made for the European Corn borer in Missouri under the direction of the Missouri Plant Inspection Service. The work was done by K. C. Sullivan, S. R. McLane and G. A. Tumbleson, deputies, under the direction of Dr. L. Haseman, chief inspector. The European Corn borer, a pest of European origin has gained a foothold in Massachusetts and New York and is causing very serious damage. Besides attacking corn it is also a pest of over 100 other plants including many which are classed as nursery and green house plants. Its favorite food plant however, is corn and should it gain a foothold in the middle western states in the corn belt it would practically revolutionize agriculture. Just recently this pest was found in Eastern Ontario, Canada and a little later a large area in Western Ontario was found to be infested. This brings it within a short distance of Detroit, Michigan and dangerously near the corn belt. In one field in Ontario it caused a commercial loss of twenty or twenty-five percent and should it continue to spread down into the corn growing states where the seasons are longer it would undoubtedly cause a much greater loss. This pest was probably brought to the United States in 1909 on Hungarian broom corn and as a quantity of this imported broom corn was shipped to and used in Missouri broom factories it is possible that this destructive pest may already be present in Missouri. One of the first acts of the Missouri Plant Inspection Service in 1920 was to promulgate a quarantine prohibiting the shipping into Missouri any plants or plant parts from the known infested areas in the east upon which the pest might gain entrance. This was done in order to prevent if possible any future introduction of the European Corn borer into Missouri. In addition to this a large amount of inspection work was and is being done especially in the vicinity of broom factories. If the European Corn borer has already found its way into Missouri, which is not at all improbable, it is necessary that it be found and eradicated as quickly as possible. As some of the broom corn imported from Hungary was used by Missouri broom factories in 1909-10 one of the first things that the Plant Inspection Service did was to locate and get in touch with these broom factories and later an inspector was sent to each factory and a thorough inspection was made of corn fields and especially sweet corn fields, in the vicinity of the factories. Also some inspection work was done in the vicinity of some Corn Cob Pipe factories. The corn-cob pipe factories obtain corn cobs from widely separated communities in the state and it was not at all unlikely that the pest might be brought to the factory in corn cobs and later escape to the corn fields near the factory. For this reason inspections were made in some of the communities near pipe factories.

Inspections were made at the following places: Jefferson City, Washington, St. Charles, St. Louis, Ste. Genevieve, Bland, Windsor, Canton, and Chillicothe.

At the above named places thorough inspections were made in many cases requiring several days. Whenever possible the inspector called upon the proprietor or manager of the broom factory and in every case the broom factory officials were more than glad to do everything in their power to help in the work. Besides the inspection work done at the above named places many corn fields were inspected in other parts of the state at different times during the summer.

At no place was the European Corn borer found and the Missouri Inspection Service feels that up to the present time it has not made its way to Missouri. However, as the European Corn borer is a new pest in the United States and as it was probably present in Massachusetts and New York about ten years before it was found it is still possible that it may be present in Missouri. For this reason the Missouri inspection service is doing everything possible to find it if it is present and during the summer of 1921 still further inspection will be made.

The European Corn borer is a medium sized moth the male of which has a wing expansion of about one inch, the female a little more. The front wings of the male are reddish brown while the hind wings have a greyish tinge. The front wings of the female are of a dull yellowish color streaked more or less with brown while the hind wings are grayish brown in color. Under Missouri conditions the adult would probably appear early in May. Soon after eggs would be deposited upon corn and other host plants and in June the greenish colored caterpillars would appear. When the caterpillar becomes full grown it is brownish or pinkish in color, from one fifth to an inch long with dark spots and tubercles on its body and has a brown shiny head. It is the caterpillar or larvae stage of the insect that causes the injury. It is a boring insect and burrows within the roots stalk, ear and tassel of the corn plant causing a weak, sickly plant and poor pollination. The pest and its work is easiest to detect just after the tassels appear. It passes the winter as a full grown caterpillar within its burrow in the host plant. The present known method of control consists of destroying the plant in which the pest is wintering or by utilizing it in some manner. Where corn is used for ensilage or the fodder is shredded the caterpillars are destroyed. Clean culture also helps to keep the pest down. In Massachusetts and New York where the insect is bad, large sums of money have been spent in collecting corn stalks, weeds and etc., during the fall and winter and burning them in order to destroy the caterpillar. The Missouri Plant Inspection Service is doing everything in its power to keep this destructive pest out of Missouri.

SWEET POTATO INSPECTION

During the past few years the Sweet Potato weevil has become a verv serious pest in some of the Southern States also some fungus diseases such as black rot, foot rot, and dry rot have caused a large amount of damage to sweet potatoes with the result that many of the Southern States have promulgated rules and regulations governing the inspection and transportation of both seed sweet potatoes and sweet potato plants. The sweet potato weevil is not present in Missouri and the Plant Inspection Service intends to keep it out, however, some of the sweet potato diseases have been found in certain sections of Missouri to some extent but not serious.

Some of the states of the south on account of the sweet potato weevil and the sweet potato diseases will not allow either seed sweet potatoes or sweet potato slips to enter their state without first being inspected. Every year hundreds of bushels of Missouri grown seed potatoes and thousands of Missouri grown slips are shipped south and for the past two years the Plant Inspection Service has been called upon to inspect these seed potatoes and slips. The sweet potato industry in Missouri is growing rapidly each year and it is just as important that this industry be protected from the attack of dangerous insect pests and plant diseases as any other. The Plant Inspection Service is performing a real service to the sweet potato industry of the state by inspecting large quantities of both seed and slips.

Certificates were issued to the following sweet potato growers during the year 1919-20:

Bushman Company, Poplar Bluff
Davis, Silas, Poplar Bluff
Davis, W. D., Poplar Bluff
Ely & Company, H. S., Neosho
Peterson, H. W., Poplar Bluff
Schilser, Fred, Poplar Bluff
Shull, C. A., Neosho
West, W. G., Poplar Bluff
Walker, W. A., Neosho

OTHER IMPORTANT INSECT PESTS AND PLANT DISEASES

Some of the dangerous insect pests and plant diseases which the Missouri Plant Inspection Service is watching closely and which have not as yet been introduced into Missouri are the Gypsy moth, the Brown tail moth, the Bean Lady beetle, the Cotton Boll weevil, the Pink Cotton Boll worm; the white pine blister rust, chestnut blight and others.

The Gypsy moth and Brown tail moth are insects of European origin which have caused millions of dollars of damage to fruit and forest trees in the New England States and during the past year new outbreaks of the Gypsy moth have been discovered in New Jersey and Pennsylvania. Both of these pests are very common in Europe and have in recent years been sent to the United States in shipments of nursery stock. During the spring of 1920 a shipment of apple seedlings from France arriving in Missouri was found to harbor nests of the Brown tail moth. In inspecting the stock the nests were found and destroyed and the shipment fumigated thus possibly preventing an outbreak of the insect in Missouri.

The Bean Lady beetle is a dangerous insect which is very common in the Western States. It feeds upon beans and related plants. Recently it was accidently introduced into Alabama where it has rapidly spread over a large area of the state and caused serious losses.

The Cotton Boll weevil has spread from Mexico over practically the entire cotton growing region of the United States but has not as yet gained access into Missouri.

The Pink Cotton Boll worm just recently has been found in Texas and Louisiana where it is causing very serious damage and large sums of money are being spent in an effort to eradicate it. It was introduced from Mexico and is the most serious cotton pest known.

Both the white pine blister rust and the chestnut blight have caused very serious losses in the eastern part of the United States and on account of these diseases it is unlawful to ship certain kinds of nursery stock subject to infection from the infected regions.

The Missouri Plant Inspection Service is watching closely these and other dangerous insect pests and plant diseases with the object in view of keeping them out of Missouri, and is working towards the control and eradication of those pests and diseases that are present.

Forest Planting in Southern Michigan[1]

By L. J. Young,

Associate Professor of Forestry, University of Michigan

The text of this paper is hardly so broad as its subject, since it is confined to the planting done by the Forestry Department of the University of Michigan in the vicinity of Ann Arbor.

Plantations were started within a year after the establishment of the department to increase the facilities for instruction, to afford opportunities for research later on and to serve as demonstration areas to the public. Since the university is located in a strictly hardwood region, the only way in which readily accessible stands of conifers could be had was by planting, so this sort of work was pressed rapidly during the early years. Hardwoods, however, have not been neglected but have received equally as much attention as the conifers.

In addition to lands owned by the university, much larger areas, belonging to the local power company, have been restocked with a variety of species.

Sowing methods have been employed only with a few of the nut trees and not even atttempted with conifers, since all early experiments along this line resulted in absolute failure.

The climate of this locality is not one that is conducive to an easy life for the young forest tree of any species when set out in the open amid unnatural surroundings. A mean annual precipitation of twenty-eight inches furnishes no great margin of safety, and when combined with an erratic distribution, that margin becomes still less. There is a tendency toward dry and rather hot summers. Little droughs of two or three weeks that are apt to come in May and early June are often especially provoking. In 1917, for example, there was no rain worthy of the name from the completion of planting in the middle of April until late in September. Long and severe winters occur every two or three years, often without a great deal of snow, so that the soil is frozen deeply. The change from winter to spring is usually a prolonged process with much alteration of cold nights and warm

[1] Read before the annual meeting of the Society of American Foresters, at New York, N. Y., December 20, 1919.

days, thus causing a great deal of frost heaving on wet and heavy soils. The soil shows all the usual variability of glacial drift, from sand and gravel to the heaviest clay, with hardpans often occurring within a foot or two of the surface.

On all of the better soils, a very heavy, tough sod soon forms, serving to increase costs and add to the difficulties of the trees in getting established.

The only enemies that have been at all serious are mice, rabbits and a few insects. Mice have caused a varying amount of damage, confined chiefly to red oak, sugar maple, chestnut, basswood, hickory, black locust, yellow poplar, Scotch pine, Douglas fir, Norway spruce, and western yellow pine. The only species that have been entirely free from this sort of damage are white elm and white pine. By 1917, mice had become such a pest that all areas of hardwoods and yellow pines were poisoned.

In the beginning, rabbits were a negligible quantity, but since the prohibition of hunting a few years ago, have steadily become more numerous, so that special measures of control are now necessary. Snaring in the winter has proven very effective.

Among the insects, the locust borer, the oyster shell scale on white ash, the larvæ of the June bug, and certain defoliators have caused the most damage.

During the first few years after planting, the borer threatened to ruin the stands of black locust, but within the last five years, the apparent damage from this source has decreased decidedly, and a good stand still remains.

Oyster shell scale became so bad on white ash as to force the clear cutting of all stands as a precaution against its spread to others of its numerous host species in adjoining stands.

The June bug did little damage in early plantings that followed closely upon the use of the land for agriculture. In recent plantings, however, they have in several cases caused the death of as much as three-fourths of the trees in the first summer.

Box elder, basswood, and white elm have suffered from time to time most severely from attacks of defoliators, though sugar maple, white ash, black walnut, and chestnut have also been damaged enough in this way to deserve mention. A few small spots of white pine have been stripped of foliage on three occasions by the sawfly. Tamarack has not been planted in stands, because of the prevalence of the sawfly.

The white pine is now infested to quite an extent with Chermes, though no damage is apparent, as the enemies of Chermes seem to be holding it pretty well in check.

In addition to the scale, white ash has been badly damaged by a twig borer.

Climatic factors also have contributed their share to the quota of damage. A severe hail storm in 1916 caught the leaders of white pine, Douglas fir, western yellow pine and Norway spruce just at the period of rapid elongation and broke off from 10 to 15 per cent. A sleet storm in the following year caused heavy damage to white pine leaders, but very little in the case of other conifers.

Late frosts have killed back all new shoots at intervals of three to four years on Douglas fir, Norway spruce, catalpa, Russian mulberry, black locust, red oak, and white oak. The same frosts have killed the newest leaves on yellow poplar, white ash, and black walnut but without damage to the stems.

Severe winter killing has occurred only with catalpa, osage orange, and chestnut. Catalpa trees 14 years old were killed back to the ground during the winter of 1917-18.

Windfall damage has been limited to Scotch and Austrian pines, caused by a wind of unusual strength in November of last year.

All of the first plantings were established by first plowing and cultivating the areas thoroughly and then placing the trees in a slit made and closed with a spade. With one exception, these were highly successful, resulting in a catch of over 95 per cent.

On a few areas, squares of sod were stripped off with a grub hoe and the trees set in a slit made and closed with a spade. The soil was a heavy clay, and subsequent growth has been slow, though the catch was over eighty per cent.

On all the heavier soils, cultivation of the area has resulted in a dense stand of weeds for several years after planting, which not only interferes with the development of the young plants but incurs the hostility of neighboring farmers. As a result, all of the more recent work has been done with the grub hoe, stripping the sod from a sixteen-inch square and digging a hole, not a slit, for the plants. The catch with this method has varied from 50 to 95 per cent, the poorer ones being due, in most cases, to unfavorable site conditions and poor stock rather than to the planting method.

Sowing has been done in drills and seedspots. Drill sowing, preceded by cultivation of strips has been very successful with red oak.

Seed spots with red oak and black walnut have given good results, but with hickory have practically failed. It might be mentioned, however, that planting hickory has not been any more satisfactory on the sites where it has been tried.

In the first plantings of conifers, where the soil was cultivated, 2-0 stock was used throughout, but where the grub hoe method is used, stronger stock has been found necessary, especially on the heavier soils. The main trouble in these latter cases seems to have been the encroachment of the sod, resulting in a much lower catch and slower growth in the early years. As a result of our experience, the present practice is to use 2-2 stock with white pine, Norway spruce, and Douglas fir and 1-2 stock with Norway, Scotch, and western yellow pines. Unfortunately, the parallel plantings made with different ages of stock of the same species were placed upon privately owned lands and were allowed to run for a short time only. One case will illustrate the general trend of results obtained. Two plantings of white pine were established side by side on level ground with all conditions the same, except that one was started as 2-0 stock and the other as 2-2. At the end of two years, the 2-0 stock showed a catch of 52 per cent, the other 95 per cent; the average height of the 2-0 stock was five inches, of the other 18 inches.

All hardwoods have been started as one-year seedlings, except cottonwood, which was established by cuttings.

Spacings used have been 3x3, 2x4, 4½x4½, 5x5, 6x6, 7½x7½, 10x10. The 2x4 spacing was used only in seed-spot work; the 10x10 only with cottonwood. In a few cases parallel plantings have been made with the same species, using two or three different spacings. The results of these are already instructive.

Three areas of black locust were set in 1906 with spacings of 3x3, 4½x4½ and 6x6. Measurement of all the trees on these plots last year showed the growth to have been as follows:

Spacing	Average d. b. h.	Average height	Maximum d. b. h.	Maximum height	Basal area per acre
3x3	3.1	28.2	6.2	39.5	66.67
4½x4½	3.4	28.8	6.3	39.5	58.65
6x6	3.7	28.4	6.5	36.2	37.8

These figures represent the growth during 14 years after planting.

The present stand per acre in each case is as follows:

Spacing	No. trees per acre	Per cent of loss	Basal area per acre
3x3	1,222	75	66.67
4½x4½	925	57	58.65
6x6	508	58	37.8

Since the per cent of trees dropping out has been modified very considerably by the work of the borer, these figures can not be considered as normal.

A better example of the effects of spacing is furnished by two plots of white pine planted in 1904 with spacings of 3x3 and 4½x4½. Based on measurements made in the fall of 1920, the results have been as follows:

Spacing	Average d. b. h.	Average height	Maximum d. b. h.	Maximum height	Basal area per acre
3x3	2.7	20.8	5.3	30.3	141.34
4½x4½	3.3	21.8	6.2	33.8	118.74

The present stand per acre follows:

Spacing	No. trees per acre	Per cent of loss
3x3	3,377	30.3
4½x4½	1,945	9.6

The relative condition of the stands in the fall of 1916 is shown in the following table:

Spacing	Average d. b. h.	Average height	Maximum d. b. h.	Maximum height	Basal area per ucre
3x3	2.3	17 0	3.6	20.9	99.67
4½x4½	2.5	16.0	4.8	24.8	75.00

The 1920 figures, showing the results of 17 years of growth, indicate clearly that most of the advantages lie with the wider spacing. The cost of establishment was about one-half that of the 3x3; the average height and diameter are now greater; the stand closed over only about two years later; and the individual trees have the branches shaded out within one or two feet of the height to which they are killed in the more closely spaced stand; the loss of trees through suppression has been less than a third as great. So far, the stand with wider spacing has failed to equal the basal area of the other, but this difference will probably continue to grow smaller rather more rapidly than it has in the past, though, during the past four years, the stand with 4½-foot spacing has gained only two square feet over the other. The race between them from now on will be an interesting thing to watch.

In view of the fact that these stands are growing south of the natural range of white pine in this part of the state, it was to be expected that their development would fall below that of those found well within its original habitat. However, a comparison with the yield table for Quality I white pine in New Hampshire, given on page 21 of the bulletin, "White Pine Under Forest Management," by E. H. Frothingham, shows that such has not been the case, especially with the 4½-foot spacing. If values for the age of 17 years are computed by interpolation from Frothingham's figures, they run as follows:

	New Hampshire stand	Michigan stand
Average height	18.5 feet	21.8 feet
Average diameter	3.34 inches	3.3 inches
Basal area per acre	86.8 square feet	118.7 square feet
No. trees per acre	1,441	1,945

The figures for average height are not exactly comparable, since those for New Hampshire are the average for dominant trees only, while those for Michigan are for all the trees in the stand. The character of the soil in this case makes these results even more surprising, since it is composed largely of sand and had been badly worn out by a long period of wasteful agricultural use. Its one virtue lies in its generous depth.

In all cases up to the present stage of development, the conifers planted, intolerant as well as tolerant, have demonstrated their ability to produce and maintain good forest conditions in pure stands. Ground cover of all sorts disappeared as soon as the stands became closed, and a good forest floor has been formed. These conifers include the Scotch, white, Austrian, and western yellow pines, Douglas fir (Rocky Mountain form), and Norway spruce. (All attempts to grow stock from Pacific Coast seed of Douglas fir have failed because of winter killing, even in winters that are unusually mild for this locality.)

On the other hand, all of the intolerant hardwoods planted have lacked this ability. With the exception of black locust stands during a short period immediately after their closing, stands of these species have a heavy ground cover of grass, and, consequently, no forest floor. These species include white ash, white elm, white oak, catalpa, and Russian mulberry. Stands of other intolerants, red oak, osage orange, hickory, chestnut, black walnut, and cottonwood have not yet closed, so no positive statement concerning them in this respect can be made, though a small part of one sowing of black walnut on exceptionally good soil shows the ground cover entirely driven out. This condition will probably be temporary, as it was with black locust. Yellow poplar has been planted only in mixture with white pine, so we have no demonstration of what a pure stand would do.

Basswood, a medium tolerant here, will probably make a better showing when the stand closes.

After making a very promising beginning, considerable portions of pure stands of white elm and white ash seem to have stagnated.

Throughout a strip immediately adjacent to a stand of black locust, box elder has made excellent growth and has succeeded in eliminating ground cover, though no forest floor has accumulated. This particular stand furnishes a striking illustration of the beneficial effect of black locust upon soil. Sugar maple is the only hardwood of high tolerance planted and has run true to form in maintaining an excellent soil condition.

Catalpa, chestnut, and osage orange have shown conclusively that they have no real place here. Russian mulberry has developed into nothing more than a lot of scrubby brushes. Better soil or a mixture with other species might make something out of it.

In addition to those already listed, other species in small groups that have made thrifty growth are jack and Norway pine, blue and white spruce, eastern balsam, concolor fir, hemlock, honey locust, horse chestnut, buckeye, cucumber, arbor vitæ, tamarack, European larch, European alder, sycamore, silver maple, white birch, and coffee tree.

On the basis of average annual growth in height and diameter, Scotch pine still leads all of the conifers with white and Austrian pine a close second and Douglas fir, western yellow pine, and Norway spruce in the order named. The relatively poor showing of Norway spruce is largely due to its location on a poor spruce site.

Among the hardwoods, cottonwood ranks first with sugar maple second and the other species in the following order: Box elder, white elm, yellow poplar, red oak, catalpa, white ash, white oak, black walnut, Russian mulberry, basswood, osage orange, chestnut, and hickory. However, a large part of the differences in growth is undoubtedly due to soil variations rather than to inherent differences of the species themselves. In determining the above order, the growth made by the best stand of each species was used. Red oak furnishes an illustration of the variability in soils. Several stands of this species of nearly the same age are located on various parts of the area. In these stands, the average annual height growth for the whole life of each one ranges from 0.43 of a foot to 0.92.

The details of the growth made by each stand up to the time of the last measurement (complete measurements are made at five-year intervals) are shown in the following table:

Species	Age, years	No. trees per acre	Original spacing, feet	Average d. b. h., inches	Average height, feet	Maximum d. b. h., inches	Maximum height, feet	Total basal area per acre, sq. ft.	Average annual growth	
									D. b. h., inches	Height, feet
Scotch pine	17	1,800	4x4	3.6	25.7	7.7	41.5	127.8	0.21	1.51
Scotch pine	14	....	irreg.	2.5	21.1	5.9	33.0	....	0.18	1.51
White pine	17	3,377	3x3	2.7	20.8	5.3	30.3	141.3	0.16	1.22
White pine	17	1,945	4½x4½	3.3	21.8	6.2	33.8	118.7	0.19	1.28
Austrian pine	14	2,244	4x4	2.9	17.9	5.2	24.7	104.9	0.20	1.28
Douglas fir	14	1,138	4x4	1.3	11.1	2.8	17.2	9.321	0.09	0.79[a]
W. yellow pine	11	825	6x6	1.3	7.6	3.1	13.9	8.258	0.12	0.69
W. yellow pine	14	....	irreg.	1.6	10.9	4.8	18.7	....	0.11	0.78
Norway spruce	15	3,188	3x3	....	6.5	......	21.1	....	....	0.43
Cottonwood	5	207	10x10	0.8	9.7	1.7	15.2	.621	0.16	1.94
Sugar maple	12	2.750	4x4	1.3	14.0	2.6	21.8	25.98	0.11	1.16
Sugar maple	12	1.555	5x5	1.4	13.9	3.5	20.6	17.04	0.11	1.16
Box elder	12	1,081	6x6	1.2	11.4	3.2	22.0	0.55	0.10	0.95
Box elder	12	2,203	4x4	1.2	13.2	4.0	26.8	18.66	0.10	1.10
White elm	12	....	5x5	1.4	12.8	3.8	24.0	....	0.12	1.07
Yellow poplar	14	928	4x4	1.5	15.0	3.0	22.4	12.10	0.11	1.07[b]
Red oak	14	1.026	4x4	0.8	8.4	2.6	17.9	3.96	0.057	0.60
Red oak	12	1,019	5x5	....	6.6	......	16.7	....	....	0.55
Red oak	12	308	6x6	....	5.2	......	13.7	....	....	0.43
Red oak	12	573	5x5	0.8	8.6	2.3	15.4	3.822	0.066	0.71[c]
Red oak	12	680	5x5	0.9	9.1	3.0	19.6	6.170	0.075	0.76[d]
Red oak	12	522	6x6	0.7	8.6	2.1	16.2	9.31	0.06	0.71[e]
Red oak	13	980	6x6	0.8	8.1	2.2	17.2	3.712	0.06	0.62
Red oak	13	829	6x6	0.6	7.1	2.8	16.4	2.261	0.05	0.55[f]
Red oak	12	526	6x6	0.9	11.1	2.4	17.6	2.456	0.075	0.92
Catalpa	14	1 884	4x4	1.5	11.7	6.7	31.1	24.16	0.11	0.83[g]
Catalpa	13	2,780	4x4	1.4	11.6	3.6	18.6	30.58	0.11	0.89
Catalpa	15	2,218	4x4	1.3	10.5	4.1	22.5	31.096	0.09	0.70
White ash	12	1,200	6x6	....	7.1	......	15.9	....	....	0.59
White ash	14	2,500	4x4	1.1	11.7	2.3	19.0	17.500	0.08	0.83
White ash	13	1,100	6x6	1.3	11.4	3.3	22.3	9.700	0.10	0.87
White oak	13	1,717	4x4	....	8.1	......	15.5	....	....	0.62
White oak	11	839	5x5	0.2	4.8	0.7	9.4	0.168	0.018	0.44
White oak	14	671	5x5	....	3.7	......	11.2	....	....	0.26
Black walnut	11	606	5x5	0.4	6.1	1.4	10.1	.545	0.036	0.55
Black walnut	14	2,085	5x5	....	5.8	......	11.9	....	....	0.41[h]
Black walnut	8	550	2x4	....	4.7	......	8.1	....	....	0.60[i]
Russian mulberry	13	1,887	4x4	....	7.8	......	17.7	....	....	0.60
Basswood	13	1,701	4x4	0.8	7.2	3.1	16.3	5.920	0.06	0.55
Osage orange	15	2,205	4x4	....	6.3	......	20.3	....	....	0.42
Chestnut	14	128	6x6	....	4.9	......	9.3	....	....	0.35
Hickory	10	120	4x4	....	2.6	......	6.0	....	....	0.26

a Now mixed with *P. ponderosa*. b Mixed with white pine. c Seed spot in fall. d Seed spot in spring. e Seed spot in spring. f Seed spot in spring. g Mixed with Scotch pine. h Seed spot in fall. i Seed spot in spring.

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HYPERTROPHIED LENTICELS ON THE ROOTS OF CONIFERS AND THEIR RELATION TO MOISTURE AND AERATION

By GLENN G. HAHN, *Scientific Assistant*, CARL HARTLEY, *Pathologist*, and ARTHUR S. RHOADS,[1] *Assistant in Forest Pathology, Investigations in Forest Pathology, Bureau of Plant Industry, United States Department of Agriculture*

INTRODUCTION

At the Bessey Nursery of the United States Forest Service at Halsey, Nebr., warty excrescences were observed upon the roots of coniferous seedling stock during the shipping season of 1915. Such excrescences occurred on all pine species grown there. They were so abundant on western yellow pine (*Pinus ponderosa*)[2] that the possibility of a parasite as the causal agent was suggested, and the forest officers properly questioned the advisability of shipping the stock to other regions.

Attempts were made by the writers to obtain evidence of a pathogenic organism, but always with negative results. This experimentation consisted of (a) incubation in moist chambers of portions of roots bearing excrescences, (b) insertion of the interior portion of the excrescences, removed with aseptic precautions, into nutrient agar, and (c) inoculation of portions of the excrescences into roots of healthy 2-year-old and 4-year-old *Pinus ponderosa* stock.

After the failure to obtain evidence of a pathologic organism, a histological examination was made, which showed that the excrescences had the structure of the hypertrophied lenticels (Pl. 44) so commonly seen in many dicotyledonous plants.

DESCRIPTION

The hypertrophied lenticles are found both upon the main tap root (Pl. 45, B) and upon the lateral roots, not only close to the ground level and upon the stems proper but also on the tap roots as far as 14 inches (36 cm.) below the surface of the soil.[3] On the stems of conifers the hypertrophied lenticles usually occur only on the basal portions of trees growing in abnormally wet situations (Pl. 45, A) or on parts otherwise submerged. In exceptionally humid situations they may occur occasionally on parts of the stems above the soil surface.

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[1] The writers wish to acknowledge helpful suggestions from Dr. B. E. Livingston, of the Johns Hopkins University, and Dr. T. H. Goodspeed, of the University of California.

[2] All the western yellow pine referred to in this paper was the type sometimes referred to as *Pinus ponderosa* var. *scopulorum*, from eastern Rocky Mountain seed.

[3] In all probability hypertrophied lenticels will be found at much greater soil depths on the roots of older trees.

On the small roots the hypertrophied lenticels occur most commonly, but not always, at the junction of a lateral root or rootlet with its parent root, usually originating immediately above the point of origin but also subtending, at the sides or immediately below, the root or rootlet in question. This agrees with the findings of De Vaux (*5*)[1] on normal lenticels, who reports that primary lenticels on roots are always at the bases of root branches, though secondary lenticels are sometimes formed later at other points. It was this coincidence of lenticels and root branches that caused some botanists during the early part of the nineteenth century to believe lenticels equivalent to buds, a doctrine attributed to De Candolle (*7; 13, Vorwort*) and overthrown by Majer (*13*),[2] Unger (*22*), Terras (*19*), and others.

The excrescences vary greatly in size and shape, from minute circular areas 0.5 mm. in diameter to bands nearly encircling the larger roots in cases where two or more lenticels have become laterally confluent. Around the root crowns and the bases of the submerged stems large, wartlike patches may occur, 5 to 8 mm. in diameter and projecting 1 to 3 mm. above the surface of the bark. Examination with a dissecting microscope shows these excrescences to be made up of a very loosely piled mound of pale yellowish tissue. As a general rule these mounds of loosely piled cells split in a stellate manner, the segments recurving outward, occasionally leaving a few filamentous columns standing by themselves in the center. Such structure is evident only when the young trees have been removed from the ground with great care, for the slightest touch upon these loose-lying columns causes them to crumble instantly to a flat, powdery mass, especially when they are dry. On the bases of still older stems 1 to 2 inches (2.5 to 5 cm.) in diameter that stand for a large part of the growing season in water or poorly drained soil, the bark, which is here considerably thickened, exfoliates in patches of varying size, revealing irregularly connected flattened masses of cells, or, more rarely, unbroken areas of such cells 1 inch (2.5 cm.) broad. On some pines these excrescences frequently become so abundant that considerable areas of the lower stem and the tap root are covered by them (Pl. 46, B). After the cessation of growth in the lenticels, these excrescences become dark root-brown and gradually slough off.

The lenticellular excrescences vary in different conifers from loosely connected, more or less divergent, columnar masses crumbling at the slightest touch, common in the pines, to fairly compact, corky masses usually seen in the trees of other coniferous genera.

Histological examination of the excrescences at once proves the white, spongy tissue to consist of more or less loosely connected masses of cells developed from the phellogen. Plate 44 illustrates a cross section of

[1] Reference is made by number (italic) to "Literature cited," p. 264–265.

[2] This seems to be the 1836 paper attributed to Mohl by Haberland (*7*). Mohl apparently directed the work of Majer and wrote a preface for the dissertation, but Majer was the author of the paper itself.

one of these hypertrophied lenticels on a root of *Pinus rigida*. The outgrowths consist of homogeneous parenchymatous elements, more or less radially elongated, sometimes very much so. The individual cells are thin-walled with a thin layer of cytoplasm.

SPECIES AFFECTED

Stahl (*18*) states that all trees which have lenticels on the stems also have them on the roots. De Vaux (*5*) reports the presence of lenticels on the roots of a large number of tree species, including a number of conifers. For one species of Ephedra he states that lenticels are found only on the roots. He states that especially in *Pinus maritima* the lenticels on the roots are larger than those on the stems. This author was able to find or to produce lenticel hypertrophy on some part of the plant in 60 per cent of the 155 plant species considered but was unable to secure any hypertrophy on the representatives of the several coniferous genera which he studied. On roots less than 3 mm. in diameter he found the normal lenticels so small that the microscope was usually necessary in demonstrating them. Tubeuf (*20*) lists a small number of species, of which he was able to secure lenticel hypertrophy on some part of 12 nonconifers. He, however, failed to get this hypertrophy on species of Sequoia, Thuja, and Taxus, or on *Gingko biloba* and 14 other nonconiferous species. Zach (*23*) later secured hypertrophy of lenticels on stems of *G. biloba* under certain conditions. However, a rather careful search in the earlier literature appears to justify the statement by the reviewer of Zack's paper (*16*) that no hypertrophy of lenticels had been up to that time reported on conifers.

The present writers have found hypertrophied lenticels on the roots of the following conifers: *Pinus ponderosa, Pinus coulteri, Pinus rigida, Pinus resinosa, Pinus banksiana, Pinus virginiana, Pinus sylvestris, Pinus caribaea, Pinus strobus, Pinus monticola, Pinus excelsa, Picea canadensis, Picea rubens, Picea mariana,*[1] *Picea pungens, Abies balsamea,*[2] *Tsuga canadensis, Larix laricina, Taxus cuspidata, Taxus brevifolia,* and *Araucaria bidwellii.*

Several of the species of Pinus on which the hypertrophy was found were growing in the greenhouse of the United States Department of Agriculture at Washington, D. C. It was noteworthy that plants of *Juniperus virginiana* under the same conditions in the same greenhouse apparently were free from such growths so far as could be determined. In a swamp in which the hypertrophied lenticels were found on *Abies balsamea, Picea rubens,* and *Tsuga canadensis* none could be discovered on *Taxus canadensis*. Among the pines the hypertrophied lenticels were frequent mainly on the 3-needled species, *Pinus ponderosa* and *Pinus*

[1] Material furnished by Dr. H. P. Brown, of The New York State College of Forestry at Syracuse University.

[2] Dr. James R. Weir advises the writers that he has frequently found hypertrophied lenticels on the roots of *Abies grandis* in the Northwest.

rigida, while on the strictly 2-needled *Pinus virginiana*, *Pinus banksiana*, and *Pinus resinosa* they were very difficult to find. Klebahn (*10, p. 582, 586*) states that up to the time of his publication he had not been able to find lenticels on *Pinus sylvestris*, nor had he satisfactorily demonstrated a substitution for lenticels.

Excrescences like those just described on the conifers are common and widespread occurrence on a number of dicotyledonous plants, particularly upon swamp plants such as *Sambucus canadensis*, *Rhus copallina*, *Decodon verticillatus*, and *Cephalanthus occidentalis*. Such excrescences on dicotyledonous plants have long been known under the term "water lenticels."

CONDITIONS UNDER WHICH HYPERTROPHY HAS BEEN FOUND

The lenticel hypertrophy observed on roots has been generally limited to plants growing in wet soil. Affected hemlock, balsam fir, red spruce, and black spruce have already been noted as growing under swamp conditions. All the pitch pines found with hypertrophied lenticels in the vicinity of Washington were in heavy, wet soil. There hypertrophy was very frequent on *Pinus rigida* and *P. virginiana* growing in swampy locations. The pines found so affected in the greenhouse at Washington were all growing in soil very much wetter than that in which they are usually found. The only Scotch pines found with hypertrophied lenticels were growing at the edge of an irrigation ditch in especially wet soil at a Michigan nursery. The same has been true in the most striking cases of hypertrophy at the Bessey Nursery. In a bed, a portion of which was repeatedly flooded from a leaking irrigation ditch, approximately 20 per cent of the plants showed marked cases of hypertrophy, while less than 1½ per cent of the plants showed hypertrophy in parts of the neighboring beds which were not affected by the leakage. Information has been received from Mr. W. H. Schrader that at the Monument Nursery of the United States Forest Service in Colorado the only conspicuous occurrence of root lenticel hypertrophy was during an unusually wet season. The hypertrophy here considered has been found both in heavy and in very sandy soils; in the latter case there was apparently more hypertrophy in parts of the beds to which clay had been added.

The youngest seedling observed with lenticel hypertrophy was one of *Pinus ponderosa* which was raised from the seed with its roots in a 2-ounce bottle of tap water in the laboratory. This water was not changed during the entire period of growth. The bottle was stoppered but was not absolutely sealed at the point of passage of the stem through the stopper. At the end of approximately five months the plant, which still seemed fairly vigorous, had developed a single root, which, after reaching the bottom of the bottle, had coiled itself around two or three times close to the peripheral limit of the bottle. On this tap root were a number of conspicuous, glistening, mound-shaped excrescences, as is shown, slightly magnified, in Plate 46, C. A microscopic examination of sectional preparations of these excrescences (Pl. 46, A) showed clearly their lenticellular structure. The outgrowths were so loose and delicate that the outer portions were necessarily lost in sectioning, but the figure shows enough of the bases to indicate the type of structure.

In general, root-lenticel hypertrophy has been found especially frequent not only on species like western yellow pine, which are somewhat inclined to lack fine fiberous roots, but also on individuals of other species when a strong tap root has been developed with relatively little development of laterals. Whether or not the larger lenticels are of advantage to such plants in fulfilling part of the functions that the missing laterals might have performed is of course uncertain. In this connection it is of some interest to note the finding of root-lenticel hypertrophy in Michigan on white and Colorado blue spruce (*Picea canadensis* and *P. pungens*) whose roots had been injured by May beetle larvae. It is also especially interesting that nursery trees that have not been transplanted or that are in their second season in the transplant beds show decidedly less hypertrophy than recently transplanted stock. The recently transplanted trees have, of course, lost most of their absorbing roots, while the trees transplanted the preceding season have had a chance to develop normal root system again after transplanting.

IRRIGATION EXPERIMENTS

Trees of *Pinus ponderosa* in their third year in the nursery, and two months following transplanting, were given river water from the irrigating ditch frequently during a three months' period, beginning July 11, 1917. All the tests considered in this and the following section were conducted at the Bessey Nursery in cooperation with Forest Supervisor Jay Higgins and his assistants. The water added at each irrigation was approximately equivalent to 2.2 inches (5.6 cm.) of rainfall. A bed which received 31 such irrigations during these three months showed at the end of the period 31 per cent of the trees with 8 or more distinctly hypertrophied lenticels each and a total of 57 per cent with some evidence of hypertrophy. The figures are based on an examination of 255 trees. This amount of watering was sufficient to cause more or less chlorosis, especially of the shoots which arose after the watering began. Another bed in the same section, on which the frequent watering was not started until a month later and which received during the entire three months a total of 17 irrigations, showed at the end of the period eight or more enlarged lenticels each on approximately 13 per cent of the plants examined. Other beds used as controls received the usual amount of water given at this nursery, involving six irrigations in addition to the 7.7 inches (20 cm.) rainfall during the period of three months.

These showed less than 1½ per cent of the plants with abundant hypertrophied lenticels and a total of less than 13 per cent showing any evidence of hypertrophy. The results in the most heavily watered bed and in the controls are given in Table I. The results with the pruned trees shown in the table lead to the same conclusions as the results cited above on the unpruned trees—namely, that heavy watering increased the amount of lenticel hypertrophy.

TABLE I.—*Effect of watering and top pruning on root-lenticel hypertrophy of third-year western yellow pine at Bessey Nursery, Halsey, Nebr., pruned in early July and examined September 10 to 15*

Plot.	Part removed by pruning.	Number of trees examined.		Percentage of trees with hypertrophy.		Percentage of trees with strong hypertrophy.[a]	
		Heavily watered series.	Normally watered series.	Heavily watered series.	Normally watered series.	Heavily watered series.	Normally watered series.
C	All the secondary needles [b]........	185	42	8	7	3	0
B	All the secondary needles [b] and tip of third season terminal shoot.	182	47	9	2	2	0
A	All the secondary needles [b] and entire third-season shoot..........	32	51	6	0	0	0
E	Third season terminal shoot only...	108	48	41	17	19	0
D	Half the secondary needles only [b].	58	0	31	......	17	......
F	Unpruned........................	206	72	58	11	33	0
......	Additional unpruned rows scattered among the different series..	49	71	51	13	24	3
ABC	Heavily pruned..................	399	140	9	2.9	2.3	0
DE	Lightly pruned..................	166	48	37	17	18	0
......	Unpruned........................	255	143	57	12	31	1.4

[a] Having 8 or more noticeably hypertrophied root lenticels per tree.
[b] Including the needles that had appeared on the third-season shoot as well as those produced in earlier years. Cut back to sheath but portion of needle remaining in the sheath left intact.

PRUNING EXPERIMENTS

Pruning experiments were conducted in an effort to throw a little more light on the factors controlling the lenticel hypertrophy. The tops of a number of rows of western yellow pine transplants at the Bessey Nursery were pruned with different degrees of severity during the first week in July, 1917. This is about the middle of the season of vigorous growth at this nursery. The results of a root examination three months later appear in Table I. The most heavily pruned plants showed the least lenticel hypertrophy, with the exception of plot E in the normally watered series. The percentage in this case is based on only 48 trees, only one-third as many as furnished the basis for each of the other figures in the three lower lines of the table. The pruning did not so injure the plants as to prevent growth entirely, for even those most heavily pruned reacted by sending out new shoots.

CAUSES OF LENTICEL HYPERTROPHY

Schenck (*15*) attributed lenticel growth on roots to oxygen hunger. However, the association which has been observed between moist conditions and abnormal lenticel growths, as well as experience in artifically producing lenticel hypertrophy by placing cuttings in water or moist air, have led more recent writers to suppose that for dicotyledonous plants the hypertrophies are directly due to the presence of an unusual amount of water (*5; 11, p. 72–80; 17*). It is reasoned, in the first place, that water or constantly moist atmosphere on the outside of the lenticels allows the steady growth of the lenticels, while dry or intermittently dry air tends to dry out the superficial cells of the lenticels or to increase their solute concentration, with resultant chemical changes, including cork and lignin formation. According to this idea the growth of the lenticel tissue is controlled by transpiration through the lenticels; with intense transpiration the tissues become dried and the hypertrophy is checked. The suberized or lignified layers thus formed are supposed to restrain mechanically further proliferation on the part of the cells beneath them from which the lenticel structures arise. So far this supposition seems logical, though there is as yet no basis for a quantitative estimation of the importance of tissue drying in the phenomenon.

DeVaux has advanced another theory, based on the fact that the supplying of abundant water to the absorbing surfaces and the reduction of transpiration have both been found to be followed by lenticel hypertrophy in experiments with dicotyledons. This writer supposes that both these treatments result in increased sap pressure in the plant as a whole and exert their influence entirely through increased sap pressure. He does not apparently give sufficient weight to the possibility that both decrease in transpiring surface and increase in soil moisture may involve decreased oxygen supply as well as increased sap pressure. The limited aeration of wet soils is a matter on which there is general agreement. The necessity of soil oxygen for the normal development of mesophytic plants, as indicated by common observation, has been recently confirmed by direct experiments by Cannon and Free (*3*) and by Livingston and Free (*12*). It is by no means certain that over-wet soil results in increased sap pressure in mesophytic plants, especially since the last-named authors find that a deficiency of oxygen in the soil results in some cases in decreased water absorption. The association between swampy soil and lenticel hypertrophy is at least as easily explained on the basis of oxygen hunger as by DeVaux's "hyperhydrose" doctrine.

The argument which Tubeuf (*20*, *21*) seems to consider strongest against oxygen hunger as the stimulus for lentical enlargement is the fact that enlargement can be produced in cuttings in a moist chamber. By placing cuttings with paraffined ends in moist chambers he secured lenticel overgrowth, even in cases in which an atmosphere of oxygen was provided. This seems at first glance to dispose of the oxygen-hunger hypothesis quite effectively. However, an atmosphere of oxygen would not necessarily insure an oxygen supply to the interior of a woody stem unless the lenticels were already open at the time the cutting was placed in the chamber. A section of stem removed from the plant and therefore deprived of the oxygen that it would normally get from the leaves and perhaps also from the roots, if its lenticels were closed, might easily by oxidation of stored food materials develop abnormal partial pressures of carbon dioxid in its interior tissues which would not be relieved till the lenticels were opened by the stimulated growth which Tubeuf describes. The experience reported in his later paper, in which he records interesting cases of lenticel stimulation secured by covering bark with impervious materials, and observation of lenticel hypertrophy on the swelling above a heat lesion lead him to consider the stimulation lenticel growth too complicated to be explained by any single factor so simple as humidity. He still appears to consider oxygen hunger as excluded from further consideration. However, his observation of numerous lenticels on the stem of a heart-rotted spruce is the only reference that has been found concerning abnormal lenticel growth on any part of a coniferous tree.

The intumescences produced by Atkinson on tomato (*1*) and by Douglas on potato (*6*) were clearly related in some way to excessive general sap pressure. They are not analogous cases to the root lenticels here considered, since the hypertrophy in the intumescences was, so far as can be judged from the illustrations given, mainly due to the stretching of soft tissue cells already present rather than to the formation of large masses of new cells.

It may be of some interest to note in passing that Cowles (*4, p. 553-554*) expresses himself as inclined to regard lacunar tissue in submerged parts of water plants to be a response to lack of transpiration rather than to oxygen deficiency.

The present writers' findings bearing on the factors causing hypertrophy of subterranean lenticels on young conifers are as follows:

1. Hypertrophy is apparently limited to trees with their roots in water or very wet soil. This may indicate either increased sap pressure or decreased aeration as among the effective stimuli. It seems rather improbable that there should be a significantly greater sap pressure in a mesophyte like *Pinus rigida* or a semixerophyte like *P. ponderosa* (Rocky Mountain type) in an excessively wet soil than in a plant in more normal condition. This seems especially improbable in view of the slow water absorption by the mesophytes in soil deficient in oxygen in the experiments already referred to (*12*).

2. While lenticel hypertrophy seems to be most common in soils containing clay, it has been frequently found in one nursery (at Halsey,

Nebr.) having a very sandy, well-drained soil, with a wilting coefficient[1] in the neighborhood of 3.4 per cent for the nursery as a whole, and an unusually high proportion of the soil (79 per cent) in particles between 0.25 and 0.05 mm. in diameter. The results of a mechanical analysis of this soil have already been published (*8, p. 2*). This, at first thought, indicates sap pressure rather than deficient aeration as the cause of hypertrophy. It is worthy of note, however, that in this case there was frequent artificial watering in addition to considerable rainfall, and it is therefore entirely possible that even in this case aeration was insufficient. Buckingham (*2*) found that both diffusion and molar movement of gas were slower in a wet sand than in any of the other soils, wet or dry, with which he experimented.

3. Reduction of the transpiring surface by removal of a large part of the needles, or of the terminal growth, or both, resulted in distinctly reducing the tendency to lenticel hypertrophy. (Table I.) The unpruned plants presumably had, at least part of the time, a lower general sap pressure than the pruned. The result of the experiment therefore tends to diminish the probability that there is any important causal relation between general excessive sap pressure and the hypertrophy in question.

4. The finding of the most abundant hypertrophy on roots which are deficient in fibrous laterals or whose absorbing surface has been greatly reduced by insect injury or by transplanting also tends to weaken the hypothesis that excessive general sap pressure throughout the plant is the chief cause of the hypertrophy. It is possible that roots which have little absorbing surface will take less oxygen from the soil than would better-developed root systems. An indication that this is the case is seen in the experience of Livingston and Free (*12, p. 185*) with the oxygen requirements of roots with different amounts of surface area. This association between deficient root surface and lenticel hypertrophy may therefore be an indication of a relation between oxygen deficiency and lenticel production.

The fact that lenticel hypertrophy was actually less in plants whose leaf surfaces had been reduced by pruning not only tends to decrease the probability of the "hyperhydrose" explanation; it is suggested that it is perhaps a further support for an oxygen-hunger (or carbon-dioxid excess) hypothesis. Plants with their leaf surfaces reduced during the latter part of the summer will of necessity produce less carbohydrate. The smaller amount of carbohydrate reaching the roots in consequence of the pruning might conceivably result in less respiration in the root tissues and therefore in a decreased need for oxygen. If this were the case the decreased oxygen hunger might furnish a partial explanation of the slight lenticel growth in the pruned plants.

[1] Determined by the Office of Biophysical Investigations, Bureau of Plant Industry.

Another possible connection between leaf pruning and oxygen hunger of root and stem is suggested by Prof. Livingston in a personal communication to one of the writers. A reduction of the transpiring surface by pruning should result in less absorption by the roots. If it be supposed that oxygen dissolved in water absorbed from the soil is important as a source of oxygen supply for the root tissues, a decrease in the amount of water absorbed might result in oxygen deficiency in the root tissues. This suggestion might help to explain the earlier reports of the stimulated growth of lenticels on stems of dicotyledons whose transpiration has been experimentally reduced. It obviously complicates any attempt to explain on an oxygen-hunger basis the effects of pruning on lenticel growth described in the present paper.

Of course it does not seem likely that any part of a plant accustomed to the presence of free oxygen would be likely to make much growth in the entire absence of oxygen. However, the condition existing in the soil in which the hypertrophies occurred certainly did not involve the entire absence of oxygen. Pfeffer concludes (*14, p. 115*), in spite of some conflicting evidence, that experiments have shown that reduction of the proportion of oxygen, at least in some cases, acts as an accelerating stimulus to growth.

It is of course true that any strong local growth is probably dependent on high local sap pressure. However, it is well known that such local high pressures are not necessarily dependent on excessive turgidity of the plant as a whole. Unusual chemical conditions, such as might conceivably result from local oxygen hunger, might easily cause them. The writers do not consider that oxygen hunger is established as the main cause of the lenticel hypertrophy found. They can not, however, agree with De Vaux in attributing the effect of increased soil moisture on lenticel growth entirely to increased water supply, excluding oxygen hunger as a possible factor in stimulating lenticel growth.

Experiments in which the oxygen, carbon-dioxid, and water supplies in the soil are independently controlled, as by the technic of Livingston and Free (*12*), and perhaps also with temperature control, will be needed to make a beginning on determining the relative importance of these various environmental factors in causing hypertrophy of root lenticels. Since conifers are rather difficult to handle in experimental work, poplar would perhaps be a better subject for preliminary experimentation. It seems likely, as has been suggested for hypertrophied lenticels in general by Tubeuf (*21*) and for intumescences by Hasselbring (*9*), that these unusual lenticel enlargements on the roots of conifers depend on a complex of conditions rather than on any one simple stimulus, and that with different species the conditions which call forth lenticel hypertrophy may be found to differ in relative importance.

RELATION BETWEEN LENTICEL HYPERTROPHY AND HEALTH OF PLANTS

Sorauer (*17, p. 210–219*) has used the name "tan disease" for lenticel hypertrophy on roots and stems of fruit trees. His use of the term "disease" appears justified in view of the association in many cases between the lenticel hypertrophy and a general pathological condition of the trees. The large lenticels described in the foregoing paragraphs as occurring on conifers are undoubtedly abnormal and in that sense are pathological. Since they occur only in abnormally wet situations, it is to be expected that in many cases the pines on which they have been found are unused to very moist surroundings and under the unfavorable conditions are subnormal in general vigor. The hypertrophies were first noted in a part of a nursery in which general vigor was unsatisfactory. Comparisons of the less vigorous and more vigorous plants in the section in which the hypertrophy was common showed lenticel hypertrophy present in both the weaker and stronger plants. The first examination, made by Hartley on about 200 3-year-old transplants of *Pinus ponderosa*, showed lenticel hypertrophy on a larger proportion of the weak trees than of the stronger trees. Later examinations made by Hahn on about 2,000 plants showed, particularly on *P. ponderosa*, that the greatest number of hypertrophied lenticels were associated with vigorous growth, This was true of plants in which the terminal root was rapidly advancing and the roots were large and stocky but correspondingly undeveloped as to lateral root surface. In one particular instance, however, where 2-year-old transplants of *P. ponderosa* had been badly affected by yellowing due to excessive irrigation, 50 per cent of 95 vigorous plants examined showed light occurrence of lenticel formation, while of 110 weakened and dying plants 80 per cent were found to exhibit light occurrence, and 10 per cent showed pronounced occurrence. This same bed examined a month later showed that the majority of the weak plants had died, while the vigorous plants, or those beginning to show renewed terminal growth, were alone showing freshly proliferating lenticels, those upon the dying plants becoming darkened and sloughing off. It therefore appears that lenticel hypertrophy is found on both weak and strong plants and that the conditions which bring on their formation may, if sufficiently prolonged, eventually cause the weakening and death of the plant. There is, however, so little direct connection between lenticel hypertrophy and the pathology of the conifers that it seems logical to recommend that any further investigation of the factors stimulating lenticel growth should be made from the point of view of physiology rather than from that of pathology.

SUMMARY

(1) Unusual excrescences on the roots of a number of different pines, spruces, and other conifers are found to have the structure of lenticels, much enlarged. They are produced in various kinds of soil in the presence of excessive moisture. Hypertrophy may occur on either weak or vigorous plants. Hypertrophy was decreased by top pruning and was increased by root injury. Such overgrowths have apparently not been previously reported on conifers.

(2) Conclusions of certain writers, based on work with dicotyledons, that excessive soil moisture stimulates lenticel hypertrophy mainly by increasing general sap pressure and that oxygen hunger is of no importance as a stimulus are not supported by the experience here set forth with conifers. Experiments in which the oxygen supply to the roots is varied without varying the water supply are believed necessary to settle the relative importance of these two factors.

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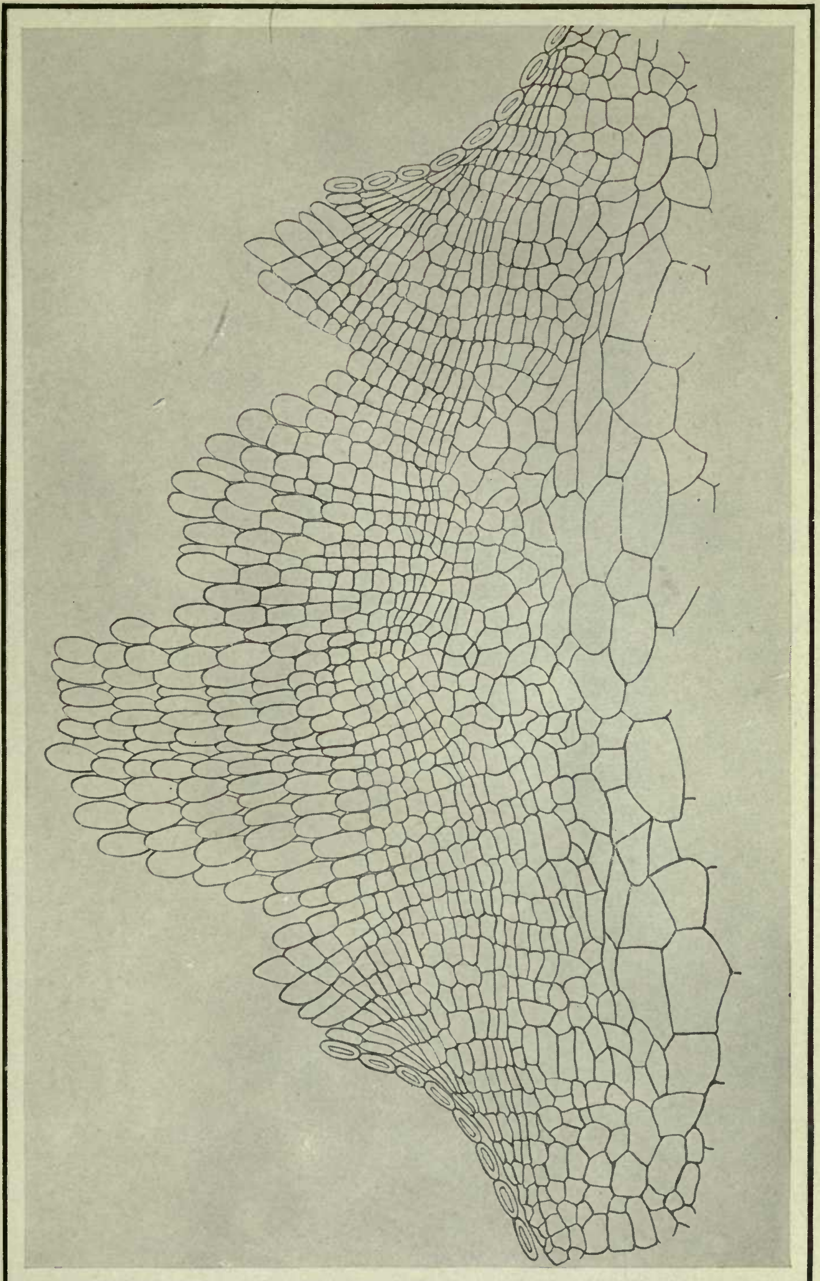
PLATE 44

Section through a hypertrophied lenticel on root of *Pinus rigida* growing in swampy situation. Approximately × 59.




A
B

PLATE 45

A.—Hypertrophied lenticels on the basal part of layering stem of *Picea mariana*, which had been covered with sphagnum. Approximately × 1¾.

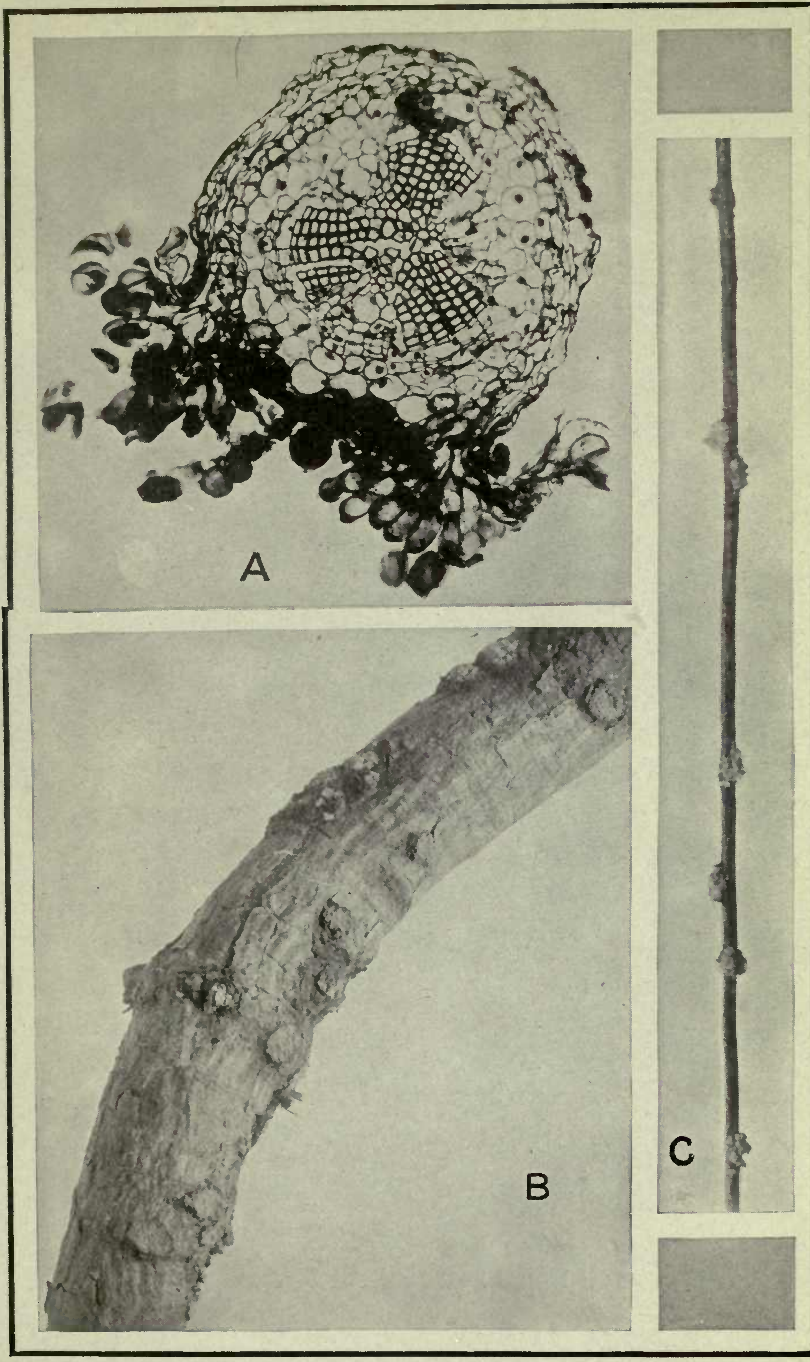
B.—Tap root of a *Pinus ponderosa* transplant, bearing an unusually large number of hypertrophied lenticels. Approximately × 1¾.

PLATE 46

A.—Cross section of the stem through one of the hypertrophied lenticels shown in C. In embedding and sectioning most of the loose outer tissues are unavoidably lost. Approximately × 112.

B.—Large patches of excrescences upon the tap root near the root crown, on *Pinus rigida*. Approximately × 1¾.

C.—Hypertrophied lenticels on root of 5-months-old *Pinus ponderosa*, grown in a loosely stoppered 2-ounce bottle, in tap water which had not been changed since the germination of the seed. The entire structure of the lenticel, which is too delicate to recover in digging roots from the soil, is here preserved. Approximately × 1¾.


A
B
C

A CHLOROSIS OF CONIFERS CORRECTED BY SPRAYING WITH FERROUS SULPHATE

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INTRODUCTION

In plants the term "chlorosis" is commonly applied to any abnormal condition whose most conspicuous symptom is a deficiency of green pigment. An exception to this general statement is perhaps the albinism of seedlings of oak, pine, and other plants which are from the first entirely lacking in chlorophyll, or, as sometimes happens in the conifers, have green cotyledons but no green in the leaves formed later. While such plants have always, so far as the writers' experience goes, died in the seedling stage, and the phenomenon must therefore be regarded as strictly pathological, the condition is not ordinarily spoken of as chlorosis. The inherited tendency on the part of healthy plants of horticultural varieties to grow leaves or parts of leaves lacking in chlorophyll is not usually considered pathological, and is better known as "variegation" than as chlorosis. True chlorosis may be due to a number of causes, such as low temperature, which hinders the formation of pigment, or lack of nitrates, which, according to Crocker (*2*),[2] at least in one of the algae, is associated with a rapid decomposition of chlorophyll. Plants in full sunlight are often less green than those less exposed, probably because of the rapid disintegration of the pigment in strong light. High temperatures very likely have the same effect (Blackman's "time factor"). Plants with deficient water supply are, on the other hand, liable to chlorosis caused by difficulty in pigment synthesis.

Much study has been given to the chlorosis of plants on calcareous soils, especially in connection with grapes in Europe. Roux (*18*) lists a large amount of literature on this subject. Recent papers by Mazé, Ruot, Lemoigne (*13*), and Gile (*6*) are well worth attention. The favorable effect of iron on plants affected with certain types of chlorosis was discovered before the middle of the last century, spraying a solution of an iron salt on chlorotic leaves having resulted in correcting the chlorotic appearance (*24*). Molisch (*14*) discusses many of the earlier experiments with iron. In a recent interesting paper, Johnson (*12*) states that spraying with iron salts is helpful for a chlorosis associated with extremely high

[1] The writers wish to acknowledge helpful suggestions from Dr. C. B. Lipman and Dr. Howard E. Pulling.
[2] Reference is made by number (italic) to "Literature cited," p. 170–171.

manganese content of the soil. Dementjew (*4*) discusses the question of whether chloroses corrected by iron are really cases of iron hunger.

The literature on the chlorosis of conifers is relatively small. Sorauer (*23*) has reported chlorosis in *Thuja occidentalis* in Europe, and Schmuziger (*21*) and Dafert and Kornauth (*3*) have noted chlorosis in spruce, without attempting to connect it with causal factors. Schmuziger reports, as do other observers on angiosperms, that the chlorotic leaves contained plastids which became green when the leaves recovered. Neger (*16*) has described in more detail a chlorosis of spruce in a cold autumn in which the yellow leaves or parts of them were found to contain much more starch than the green leaves or their green bases with yellow tips. He rather vaguely connects both current low temperature and the drouth of the preceding winter with the various phenomena observed.

Contejean (*1*) lists Scotch pine (*Pinus sylvestris*) as somewhat calcifuge, and makes the general statement that excess lime accompanied by lack of iron, or "encore plus" lack of potassium, results in chlorosis of calcifuge plants. He, however, makes no specific mention of chlorosis in any conifer. Fliche and Grandeau (*5*) attribute the calcifuge tendencies of *P. sylvestris* to the physical rather than the chemical qualities of lime soils. They find Austrian pine (*P. austriaca*), *P. halepensis*, and *Abies pectinata* doing well on strongly calcareous soils, but they find *P. pinaster* making a poor growth in plantations on calcareous soil in all cases observed and entirely refusing to grow in some cases. Deficiency in starch and chlorophyll are noted for this pine on the lime soils, and also to a very slight extent for the Austrian pine on soils with extremely high calcium-carbonate content. The chloroplasts of the chlorotic plants are said to be small. The poor condition is attributed to potash hunger, and no mention is made of iron hunger as a possible cause. Ash analyses showed the following conditions:

On good soil,

Pinus pinaster, potash 16 per cent, iron oxid 3.8 per cent, lime 40 per cent.

On excessively calcareous soil,

Pinus pinaster, potash 5 per cent, iron oxid 2.1 per cent, lime 56 per cent.

Pinus austriaca, potash 14 per cent, iron oxid 3.3 per cent, lime 49 per cent.

Sachs (*20*) reports chlorosis in young trees of *Abies balsamea*, *A. apollonis*, and *A. bicolor* and says that entirely chlorotic new growth becomes green more or less promptly after considerable quantities of solid iron sulphate are placed in ditches in the soil near the roots. No controls are mentioned, but the promptness with which the younger trees are reported to have responded to the treatment supports his conclusion that the recovery was due to the iron added, despite the fact that fast-growing chlorotic shoots, according to his own statement, usually improve in color toward the end of the season without any special treatment.

An interesting American report is that on chlorosis of *Sequoia sempervirens* by Peirce (*17*).

CHLOROSIS OF CONIFER NURSERY STOCK IN THE UNITED STATES

At several of the nurseries of the United States Forest Service in Nebraska and farther west, conifers are occasionally somewhat chlorotic The condition has become a matter of importance, however, only in the Morton Nursery, in northwestern Nebraska, and the Pocatello Nursery, in southern Idaho. Chlorosis has also been noted in conifers at the Great Basin Experiment Station in central Utah, especially in lodgepole pine (*Pinus contorta*) seedlings and transplants grown two years in the seed bed and one year in the transplant bed. At the latter locality native aspen (*Populus tremuloides*) was also chlorotic in places.

ANALYSES OF SOIL AND WATER

At all the points at which chlorosis was found, analysis (by courtesy of the United States Bureau of Soils for the nursery soils, and of Dr. J. E. Greaves, of the Utah Agricultural Experiment Station, for the Great Basin Experiment Station soils, showed the presence of carbonates as indicated by carbon-dioxid evolution. Carbon dioxid was, however, reported from sites near the Great Basin Experiment Station on which no chlorosis had been observed in either aspen or conifers, and from a nursery at which chlorosis had never been serious. In some cases the amount reported from soils on which the trees were green was greater than from those where the trees were chlorotic. The acid-digestion analyses showed for all the soils on which chlorosis was observed a considerable amount of calcium, much greater than that ordinarily found in the humid region of the United States, and in every case greater than the average of the 570 soils of the arid region reported by Hilgard (*10, p. 377*). However, there is little apparent correlation between the amount of chlorosis and the amount of calcium reported. The Utah soil on which conifers were not chlorotic yielded over 17 per cent of lime (as CaO) and 12½ per cent of carbon dioxid. The Pocatello nursery soil on which chlorosis was serious yielded more than twice as much calcium (2.9 to 4.7 per cent CaO) as Hilgard's average for arid soils. It was not an excessively calcareous soil, however, as compared with some of the soils reported in connection with chlorosis in Europe and Porto Rico, with the chalk soils reported by Somerville (*22*) on which healthy Douglas fir was growing, or with the Utah soil just mentioned as supporting normally green conifers. The phosphorus (as P_2O_5) for the Pocatello soil was reported as approximately 0.7 per cent for all the samples, an unusually high figure. This at once suggests a possible relationship, in view of the slight solubility of ferric phosphate. The other soils on which chlorosis occurred, however, did not give any such high phosphorus analysis. The fact that the solubility of ferric phosphate is sufficient to make it a good source of iron in water-culture experiments prevents any probability of a relation between the amount of phosphorous found by analysis and the availability of iron.

All the analyses indicated normal quantities of iron. The results are in agreement with the general experience that acid-digestion soil analyses yield little information of value from the plant physiological or pathological standpoint. Petrographic examination by the United States Bureau of Soils of the Pocatello soil and of the nursery soil which contained carbonates without chlorosis gave no clue to the difference between the plants on them. Acidity determinations by Dr. L. J. Gillespie, of the Bureau of Plant Industry, showed a P_H of 7.8 for the Pocatello soil and 8.4 for the nursery at which there were carbonates but no serious chlorosis. The main facts to be drawn from the examination of the soils of the different stations was that all the soils on which chlorosis occurred contained carbonates and that two of them were underlaid with limestone.

Analysis by the United States Bureau of Chemistry of the water supply showed 320 mgm. of bicarbonic acid (HCO_3) per liter of water at the Pocatello Nursery, and practically no other anions, while at the nursery at which there were soil carbonates but no chlorosis there were reported 180 mgm. of bicarbonic acid per liter, as against 450 mgm. of sulphate (SO_4) per liter. This is of some interest in connection with the difference in the amount of chlorosis at the two places, as the arid conditions made necessary the application of considerable amounts of water to the nursery beds during warm weather. The soil solutions during the periods of greatest growth must, therefore, have been influenced to a considerable extent by the character of this water. It was noted at the Pocatello Nursery that the chlorosis was more prevalent in beds which had been under nursery management for several years than in beds which had just been included in the nursery area and had therefore received less of the water.

KIND AND EXTENT OF INJURY

At the Pocatello Nursery there was so much chlorosis and the growth of affected stock was so unstisfactory that a detailed study of it was undertaken. The nursery is at an elevation of 5,200 feet, well below the lower limit of natural coniferous forest growth in this region. Precipitation for the period during which the nursery is usually free from snow (April to October, inclusive) averaged but 11.2 inches for the years 1909 to 1917, inclusive. The days are warm and the nights cool during the growing season, only 2½ months being entirely free from killing frost. The soil is a rather heavy black silt loam; composite samples from 8 to 10 points each show for three different parts of the nursery wilting coefficients of 11.7, 12.6, and 14.3 per cent, respectively.[1]

The species in which the chlorosis has been noted are western yellow pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi*), Corsican pine (*Pinus laricio corsicana*), and Douglas fir (*Pseudotsuga taxifolia*). Of the two most important species grown here, western yellow pine and Douglas fir, the former is the more susceptible, especially during its first year. During the second year, Douglas fir is also considerably affected.

The yellowing first becomes evident in the leaves of most recent growth, as reported by Sachs (*20*) for firs and broad-leaved plants. The entire foliage may be affected. In serious cases, the leaves are short, inclined to curl, and are less turgid than normal leaves (as a consequence of lack of sugars and therefore low osmotic pressure). The terminal bud either fails to develop or is dwarfed and usually abnormally light in color. The height and diameter of the stem, the length of the roots, and especially the ability to form fibrous lateral roots also appear to suffer in typical cases of chlorosis. The disease may occur in patches, or isolated yellow plants may occur. In severe cases death ensues, the parts first discolored being the first to die.

The greater part of the injury develops after height growth has mainly ceased for the season. A marked functional disturbance is indicated in the apparent inability of chlorotic plants to harden properly for the winter. Chlorotic first-, second-, and third-year seedlings of both Douglas fir and western yellow pine, though not growing with the vigor of green seedlings, continue growth later in the season and are more susceptible to injury by early fall frosts. This recalls the frost susceptibility of chlorotic redwood shoots reported by Peirce (*17*) and further suggests a relation between chlorosis and low osmotic pressure due to failure to make sugar, as in wilting. Decreased winter loss as a result of a treatment which controlled the chlorosis is shown by the data in Table I. Seedlings chlorotic during their first or second year start growth tardily or not at all the following season. The number of dwarfed chlorotic plants which die during the summer is increasingly great during the second and third years in the seed bed. In transplanting, chlorotic seedlings are discarded.

[1] Determined by the indirect method of Briggs and Shantz in the Laboratory of Biophysical Investigations, Bureau of Plant Industry, United States Department of Agriculture.

TABLE I.—*Effect of iron-sulphate spraying on mortality of western yellow pine seedlings*

Series and plot.	Age of stock during treatment period.	Number of seedlings per square foot.	Treatments. Dates.	Treatments. Strength of solution (grams per 100 cc.).	Treatments. Amount $FeSO_4$ per square foot of bed.	Dead seedlings. Sept. 3 to Oct. 22, 1917.	Dead seedlings. Oct. 22, 1917, to Apr. 23, 1918. (winter-killed).	Dead seedlings. Sept. 3, 1917, to Apr. 23, 1918.
	Months.		*1917.*		*Gm.*	*Per cent.*	*Per cent.*	*Per cent.*
I, treated	14 to 18	108	Aug. 2, 24, Sept. 3, 12, 22, and Oct. 2.	2	[a] 0.95	4	0	4
II, treated	..do....	75		1	[a] .47	5	0	5
I, control	..do....	115	....	....	....	3	8	11
II, control	..do....	80	....	....	....	4	15	19
III, treated	2 to 5	52	Sept. 3, 12, 22, and Oct. 2.	2	[a] .95	13	0	13
Do	..do....	58		1	[a] .47	14	0	14
Do	..do....	63		.5	[a] .24	14	11	24
III, control	..do....	76	....	....	....	14	9	22

[a] 0.1 pint of solution per square foot, equivalent to 0.02 inch of rain, applied to each treatment.

The prevalence of chlorosis in the Pocatello Nursery during September, 1917, was determined by examining several thousand plants of the different age classes of western yellow pine and Douglas fir. Of the first- and second-year western yellow pine seedlings 82 and 62 per cent, respectively, were chlorotic; while 74 per cent of the transplants grown two years in the seed bed and one year in the transplant bed were chlorotic. First-, second-, and third-year seedlings of Douglas fir were chlorotic to the extent of 6, 65, and 26 per cent, respectively; while 15 and 62 per cent of the transplants grown three years in the seed bed and one and two years, respectively, in the transplant bed were chlorotic.

EFFECT OF WATERING

It was at first thought that too heavy watering might have been responsible for the chlorosis at the Pocatello Nursery. While an examination of the condition of the soil did not indicate water-logging, variations in the amount of artificial watering were tested. Four plots of Douglas fir seedlings approximately 2 months old were given varying amounts of water throughout a period of slightly over two months. The results appear in Table II. The artificial watering was at first given approximately once a week and amounted to the equivalent of 0.55 inch of rain on plot D, the most heavily watered plot. Plot C received two-thirds of this amount, plot B one-third, and plot A none. After the first month the amount of water added at each watering was decreased because of the difficulty of avoiding run-off, and the frequency of application was increased. The plots in this experiment were free from chlorosis at the beginning of the period, and all of them later exhibited more or less yellowing. The amount of water applied artificially, combined with the natural precipitation, did not total an excessive amount, except possibly in plot D. This experiment was carried on in a section of the nursery in which the disease did not prove to be prevalent, and little chlorosis occurred in any of the plots. The entire number of yellow seedlings shows an increase with increased watering through all four plots for the last three counts and a somewhat less marked but similar relation for the earlier counts. The magnitude of the difference is, however, not sufficient to permit positive conclusions. Whether the apparent effect of the watering in increasing chlorosis was mostly due to the solutes in the excess water, to cooling the soil, or to hindering aeration, it is not possible to say. That the entire effect of the watering should have been due to disturbance of aeration, or temperature, seems scarcely possible in the cases of plots B and C, which received relatively little artificial watering. These plots did not seem excessively wet, but the soil of plot D was sufficiently wet to permit the development of moss—abnormally wet for this nursery.

TABLE II.—*Effects of different amounts of artificial watering on chlorosis in 4- to 5-month-old Douglas fir seedlings*

	Plot A, un-watered. [b]	Plot B, lightly watered. [b]	Plot C, moderately watered. [b]	Plot D heavily watered. [b]
1917.				
Rainfall and artificial watering (in inches):				
First half of August	Traces.	0.54 (3)	1.11 (3)	1.65 (3)
Last half of August	0.25 (3)	.34 (4)	.43 (4)	.53 (4)
First half of September	1.07 (6)	1.34 (7)	1.61 (7)	1.91 (7)
Last half of September	.71 (2)	1.07 (6)	1.43 (6)	1.83 (6)
First half of October	....	.18 (2)	.36 (2)	.56 (2)
Total, Aug. 2 to Oct. 6	2.03 (11)	3.47 (22)	4.94 (22)	6.48 (22)
Percentage of seedlings found chlorotic: [a]				
Sept. 1	7.8	11.8	10.7	17.9
Sept. 13	6.1	7.5	7.0	14.7
Sept. 22	1.7	4.3	5.1	8.4
Oct. 2	.4	2.2	2.9	4.8
Oct. 22	.4	2.2	2.6	4.0

[a] Two square feet counted in each plot. Number of seedlings per square foot at beginning of test: Plot A, 241; B, 244; C, 363; D, 278.
[b] Figures in parenthesis indicate total number of days on which rain or artificial watering occurred.

A pathologic condition may be encountered in certain conifers growing in wet situations. This condition would be unfavorable and therefore would result in subnormal vigor and growth of the plants subjected to such abnormal conditions. In studying hypertrophied lenticels at the Bessey Nursery, near Halsey, Nebr., one of the writers (*8*) conducted an experiment in heavy watering, in which irrigations approximately equivalent to 2.2 inches of rainfall were repeated 17 times during a period of three months on western yellow pine transplants grown two years in the seed bed and one year in the transplant bed. Considerable chlorosis appeared in the heavily watered beds, the plants of which were originally thrifty and free of chlorosis, while the controls remained nonchlorotic. There is also a possibility of a lack of proper aeration of the soil and of oxygen hunger as a very probable and effective stimulus in inducing chlorosis in a mesophyte like Douglas fir in an excessively wet soil.

SPRAYING WITH FERROUS SULPHATE

Spraying with ferrous sulphate was tested on western yellow pine and Douglas fir. The first tests were on seedlings of the former species approximately 14 months old. Plots 4 by 10 feet were laid out, series I in beds in which chlorosis was not serious, and series II in beds in which it was very prevalent. The two plots in each were adjacent and parallel. Care was taken to choose plots as nearly as possible identical in vigor, number of seedlings per square foot, and amount of chlorosis. One of the plots in each series was sprayed with iron-sulphate solution at the rate of 2 gm. of sulphate per 100 cc. of water, and the other was given an

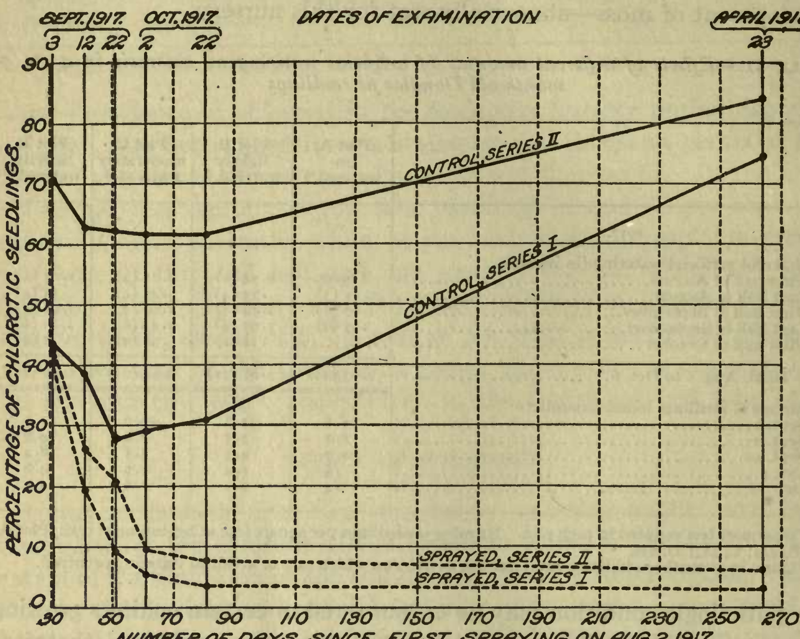

FIG. 1.—Graph showing the effect of a ferrous sulphate spray treatment on chlorosis in seedlings of western yellow pine 14 to 18 months old.

equal quantity of water only and was used as a control. The spraying was done with a hand-spray pump and was begun on August 2, 1917. In each case the plot selected for the treatment appeared slightly more chlorotic than the control at the time of the first treatment. On August 24, after two sprayings, it was evident that chlorosis had been decreased but that chemical injury to the youngest growth had resulted from the treatment. This injury is somewhat surprising, in view of the successful use of 8 per cent solutions on pineapple (*12*). The difference in results may, of course, be due to difference in the localization of the solution on the surfaces of the two plants. Conifers are very difficult to coat evenly with a spray. Also the fact that there had been practically no rain from the first treatment to the time the injury was observed may have been responsible for the degree of injury by the 2 per cent solution. In a region of heavier rainfall this solution, or even a stronger one, might be entirely harmless to conifers. The treatments were continued, but with a 1 per cent solution at the rate of only 0.1 of a pint, containing approximately 0.47 gm. of ferrous sulphate per square foot of seed bed. Sprayings with this weaker solution were made on August 24, September 3, September 12, September 22, and October 2; and the seedlings on sample areas were counted and classified as to the degree of chlorosis on different dates in September and October, and again in April of the following year.

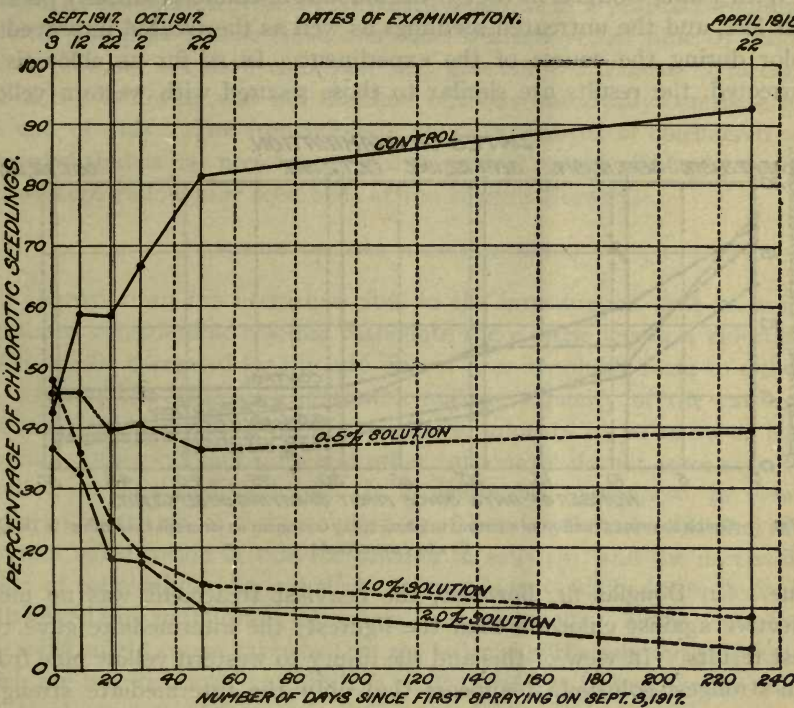

Fig. 2.—Graph showing the effect of a ferrous sulphate spray treatment on chlorosis in seedlings of western yellow pine 2 to 5 months old.

The results are shown graphically in figure 1. Decided inprovement in the color of the sprayed plots during the period covered by the counts is indicated by the data. The undiminished persistence of the good effect through the winter, a total of 6½ months after the last spraying, and the smaller percentage of winterkilled seedlings in the sprayed plots (Table I) are worthy of note.

At the time the first counts were made on the older seedlings (September 3) plots of the same size were also laid out in beds of both western yellow pine and Douglas fir of the current year's sowing and were therefore about 3 months old. The results with the young western yellow pine (fig. 2) are more striking than those with the older stock. Autumn losses, presumably due to late damping-off, were not affected by the treatments; but winterkilling was entirely prevented (Table I). The heaviest treatment seemed to give better results than the lighter ones, so far as correcting chlorosis was concerned, both at the fall and the succeeding spring examinations, but resulted after the third treatment in the blackening of some of the leaves. The chemical injury was even more marked at the time of the spring examination, when practically every seedling in all the western yellow pine plots treated with the 2 per cent solution showed chemical injury, whereas the plots treated with the weaker solution showed none.

With young Douglas fir (fig. 3) the amount of chlorosis initially present was less, and the untreated seedlings as well as the treated improved in color during the course of the experiment. In so far as chlorosis is corrected, the results are similar to those secured with western yellow

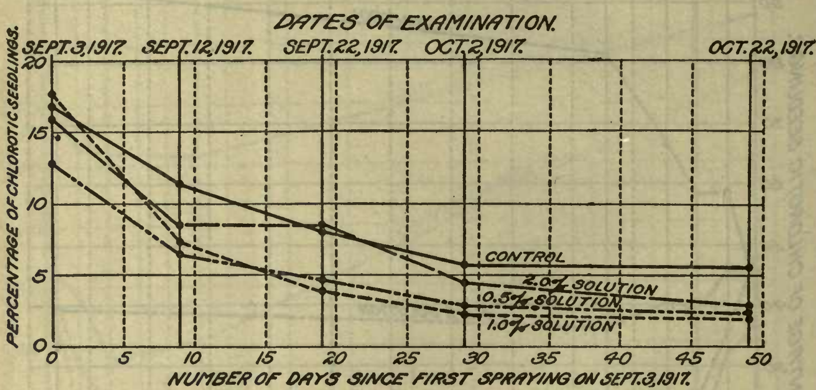

FIG. 3.—Graph showing the effect of a ferrous sulphate spray treatment on chlorosis in seedlings of Douglas fir 2 to 5 months old.

pine. On Douglas fir, however, the heaviest treatment was no more effective against chlorosis than the lightest; the intermediate gave the best results. In view of this and the injury to western yellow pine from the strongest solution, it appears that only the intermediate strength (1 per cent) should be used on conifers, at least if repeated spraying is practiced.

Though the total area counted in all the spraying experiments with first-year seedlings was small—12 square feet in the treated plots and 6 square feet in the controls—the data obtained from the counts show on the whole such consistent and decided improvement in the sprayed plots as to leave no reasonable doubt about the therapeutic value of the treatment for western yellow pine. Observations on the entire area of the western yellow pine experimental plots (200 square feet treated and 120 square feet in the controls) indicate that the sample areas on which the counts were made were reasonably representative of the entire plots.

The contrast between the treated and untreated plots of western yellow pine at the close of the experiments was very strong throughout.

No attempt was made to exclude the ferrous sulphate from the roots. In view of the high absorptive capacity for iron sulphate of the calcareous soil with which Sachs worked (*19*, *20*) and the prompt reaction (fig. 2) following the small amount of the sulphate added by the writers in the 1 per cent solution treatments on the younger western yellow pine seedlings (fig. 2 and Table I), it is believed that the effect of the iron-sulphate spraying was due to the entrance of traces of iron into the leaves, presumably mostly through the stomata, though Molisch (*14*) reports it as entering through the cuticle.

Forest officers report that 1 per cent ferrous sulphate sprayings begun in April at the Morton Nursery corrected chlorosis in 2-year-old seedlings of both jack pine (*Pinus banksiana*) and western yellow pine by June. Scotch pine did not show chlorosis; jack pine showed it most. The control of the yellowing was not absolute but was practically complete by the end of July. The iron-sulphate spray treatment is considered so successful that it has now been put into general use on all the jack pine and western yellow pine seed beds at the Morton Nursery.

VALUE OF THE EXPERIMENTS

It appears from the literature cited in the introduction that on soils containing considerable calcium carbonate there often occurs a chlorosis which can be corrected by the addition of iron in soluble form to either the roots or the leaves. The trouble-making capacity of the calcium carbonate, though not always in evidence, appears to be more or less specific. Other calcium salts and other carbonates do not seem equally effective as causes of chlorosis. It is reasonable to suppose, in view, among other things, of the precipitation of iron in alkaline solutions, the apparent substitution of iron for calcium in soil (*15*), and the nonavailability of colloidal iron (7, *11*) that the trouble was chiefly due to the lack of dissolved iron in the water of certain calcareous soils. However, in the lime soil it might conceivably be that the balance of the solution for plants which are not distinctly calciphile is so disturbed as to make more than the usual amount of iron necessary to maintain the plants in normal health on such soils. A further complication is the fact that the distribution of chlorosis in different parts of the same plant is sometimes such as to indicate that at least part of the difficulty may be due to derangements in conduction instead of or in addition to absorption failures. Furthermore, physiologists are not all ready to agree that the lack of green is really a symptom of a specific iron hunger, even in cases in which the remedial value of iron addition is demonstrated. The writers' results have made no addition to the knowledge of the immediate cause of the chlorosis or the way in which the addition of iron works in correcting it. These complications are mentioned merely to show that fundamental work on chlorosis lies in the domain of the biochemist rather than of the pathologist or the forester.

The immediately practical applications are fortunately simpler. The writers have added three gymnosperms to the considerable list of angiosperms in which chlorosis can be relieved by spraying ferrous sulphate on the surfaces of the leaves. While the best way to avoid chlorosis in coniferous nurseries is probably to avoid soils containing any considerable quantities of calcium carbonate, an entirely practicable method of treatment is offered by which chlorosis can apparently be relieved in coniferous nurseries on lime soils. At the rate at which the experimental spraying was done, using the 1 per cent solution, which on the whole gave the best results, 1 pound of the relatively cheap ferrous sulphate is sufficient for over 900 square feet of bed. While with larger stock more material would be required, the process would still be relatively cheap. Johnson (*10*), using a solution eight times as strong, reported the total cost of spraying pineapples as $0.60 per acre for each spraying. In a business as intensive as that of raising coniferous nursery stock such a cost item would be almost negligible.

RELATION BETWEEN CHLOROSIS AND GROWTH

Observations through several seasons at the Pocatello Nursery have indicated a relation between chlorosis and poor growth. In order to secure data on this relationship the seedlings in the control plots whose counts are given in figure 1 were classified by their apparent vigor of growth as well as according to their chlorotic condition. The counts showed for the first series that 23 per cent of the seedlings classed as vigorous were chlorotic, while 42 per cent of the weak seedlings were in the chlorotic class. For the second series the difference was about the same, 46 per cent of the vigorous seedlings being chlorotic against the very high proportion of 73 per cent among the seedlings classed as weak. In an effort to put this relationship on a more exact basis, specimens were selected from each class and subclass of seedlings of which a sufficient number were available to give a reasonable numerical basis, and measurements of roots, stems, and leaves were made.

METHODS OF SECURING MEASUREMENTS

The seedlings taken were selected by a process of mechanical elimination, every fifth seedling being chosen in most of the cases, so that they are believed to be representative of the groups from which they came. The leaf surface values were obtained by a method which does not pretend to give the absolute surface accurately, but which is believed to give sufficiently accurate relative values to permit a comparison of the different groups of plants.

The surfaces of the primary and secondary leaves of western yellow pine were determined separately on account of their different shapes.

The primary leaves are approximately semicircular in cross section, and for the purpose of obtaining a comparative surface value were considered as halves of cylinders having a radius equal to the thickness of the leaf midway between the base and the tip, with the length equal to the length of the leaf. The perimeter of the cross section at this point was taken as $\pi R + 2R$—that is, the sum of the lengths of the curved and the flat margins of the cross section. The surface of the leaf was taken as $S = L(\pi R + 2R)$, in which L equals the length of the leaf. A sufficient number of primary and secondary leaves from each plant were measured to allow averaging (usually from 25 to 100, depending on the number per plant). The total primary leaf surface for the plant was obtained by multiplying the surface of the average leaf by the entire number of primary leaves. The secondary leaves were in most cases in fascicles of three, and their cross-sectional shape may be diagrammed as in figure 4. The same assumptions were made in this case as in the case of the primary leaves, the leaf being taken as an exact third of a cylinder with the radius equal to the thickness of the leaf midway between the base and the tip, and the surface calculated by the formula $S = L\left(\frac{2\pi R}{3} + 2R\right)$. This formula appears to be more nearly correct than a paraboloid formula, and it is believed that it offers a better basis for comparing the leaf surface of one group of plants with that of another than would be given by statements of the average number, length, breadth, and thickness of the leaves.

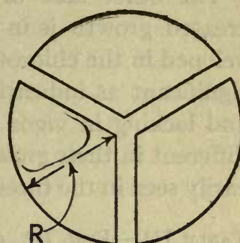

FIG. 4.—Cross-sectional shape of fascicle of three secondary leaves of western yellow pine.

INTERPRETATION OF THE MEASUREMENTS

From Tables III and IV it appears that the height and the weight of the tops, the length and the weight of the roots, the diameter of the stems at the root collar, the length and thickness of the secondary leaves, and the average total leaf surface of the plants was less for chlorotic plants than for green seedlings of the same vigor class and that terminal bud formation was most common and most pronounced in the most vigorous plants. The data indicate that the failure to form buds is related to a general lack of vigor, which in many cases is associated with chlorosis. The adverse effects of chlorosis on terminal bud formation and development is significant in connection with the high winter mortality of the strongly chlorotic seedlings.

The small size of the different parts of the plants in the chlorotic seedlings, as compared with the green seedlings, is, on the whole, fairly uniform. Two exceptions to this are, however, noteworthy. In Table III it appears that the roots of the chlorotic plants are nearly as long as those of the green plants. However, the weight of the roots was decidedly less in the chlorotic than in the green plants. This agrees with the field observations, indicating an association between chlorosis and a deficiency of fibrous lateral roots. It will be noted that the strongly chlorotic plants in the vigorous class had a root weight considerably less than that of the green plants in the weaker class. While the roots of these plants were also somewhat shorter, the weight difference was distinctly greater.

The other lack of parallelism between increased chlorosis and decreased growth is in the primary leaves. These were nearly as well developed in the chlorotic plants as in the green plants. This is considered significant as indicating that the plants which were decidedly chlorotic and lacking in vigor during the second season were not originally very different in their growth rate from the others. This relationship is most easily seen in the three columns under "Relative leaf surface" in Table IV.

TABLE III.—*Root, top, and terminal bud development of the different type classes of 2-year-old seedlings*

UNTREATED WESTERN YELLOW PINE [a]

Type classes.	Number of seedlings.	Average diameter of stem at root collar.	Tops. Average length.	Tops. Average weight.	Roots. Average length.	Roots. Average weight.	Average total weight of seedlings.	Terminal buds. Percentage of seedlings forming terminal buds.	Terminal buds. Average length.	Terminal buds. Average diameter.
		Inches.	*Inches.*	*Gm.*	*Inches.*	*Gm.*	*Gm.*		*Inches.*	*Inches.*
Vigorous, green	100	0.075	2.2	1.40	11.7	0.57	1.97	9	0.33	0.16
Vigorous, slightly chlorotic	95	.065	1.7	.77	9.7	.33	1.11	2	.23	.12
Vigorous, strongly chlorotic	22	.062	1.6	.52	8.6	.20	.72	0	....	....
Weak, green	100	.060	1.6	.54	9.6	.26	.80	0	....	....
Weak, slightly chlorotic	100	.058	1.4	.35	9.3	.18	.52	0	....	....
Weak, strongly chlorotic	100	.045	1.2	.22	9.6	.12	.34	0	....	....
UNTREATED DOUGLAS FIR [a]										
Green	50	.046	2.8	.34	9.6	.15	.50	100	.15	.08
Chlorotic	50	.038	2.3	.22	8.2	.08	.30	86	.10	.04

[a] The number of chlorotic plants in the treated plots at the end of the season was insufficient to serve as a basis for measurement.

TABLE IV.—*Leaf development of the different type classes of 2-year-old seedlings*

UNTREATED WESTERN YELLOW PINE [a]

Type class.	Number of seedlings.	Primary leaves.					Secondary leaves.				Average total leaf surface per plant.	Relative leaf surface.[b]		
		Average number per plant.	Average length.	Average thickness.	Average leaf surface per plant.	Percentage of seedlings bearing secondary leaves.	Average number per plant.	Average length.	Average thickness.	Average leaf surface per plant.		Primary leaves.	Secondary leaves.	Total.
			Inches.	*Inches.*	*Square inches.*			*Inches.*	*Inches.*	*Square inches.*	*Square inches.*			
Vigorous, green	100	37.7	1.05	0.016	3.27	100	32.1	2.61	0.023	7.89	11.15	100	100	100
Vigorous, slightly chlorotic	100	40.8	.80	.012	2.02	100	29.9	1.82	.015	3.34	5.36	62	42	48
Vigorous, strongly chlorotic	22	42.2	.83	.014	2.52	100	25.2	1.63	.015	2.52	5.05	77	32	45
Weak, green	100	31.2	.85	.013	1.77	99	23.4	1.45	.015	2.08	3.86	54	26	36
Weak, slightly chlorotic	102	46.4	.67	.013	2.08	68	18.1	1.09	.017	1.37	3.45	64	17	31
Weak, strongly chlorotic	100	38.1	.60	.013	1.41	43	13.7	1.05	.015	.88	2.29	43	11	21

UNTREATED DOUGLAS FIR [a]

Type class.	Number of seedlings.	Average number per plant.	Average length.	Average thickness.	Average leaf surface per plant.	Percentage of seedlings bearing secondary leaves.	Average number per plant.	Average length.	Average thickness.	Average leaf surface per plant.	Average total leaf surface per plant.	Primary leaves.	Secondary leaves.	Total.
Green	50	95.1	0.50	0.010	2.44	....	....	....	....	....	2.44	100	....	100
Chlorotic	50	83.0	.45	.007	1.34	....	....	....	....	....	1.34	55	....	55

[a] The number of chlorotic plants in the treated plots at the end of the season was insufficient to serve as a basis for measurements.
[b] Untreated "vigorous green" leaves taken as 100.

This difference between the first and second season's growth of the same plants is thought to have some bearing on the character of the association between chlorosis and lack of vigor. Three possible explanations of this association present themselves: (1) A general lack of vigor may predispose to chlorosis; (2) the conditions which cause reduced vigor at this nursery may also favor chlorosis, so that the two phenomena are coordinate effects of the same set of conditions; (3) the poor growth of chlorotic plants may be a result of the chlorotic condition.

The first of these possibilities has little to recommend it from the theoretical standpoint, in so far as vigor is judged by the growth rate of the tops. Sachs (*19*) finds iron-hunger chlorosis especially common in rapidly growing shoots. The evidence in Tables III and IV that the chlorotic seedlings were not seriously deficient in growth of tops at the beginning of their second season tends further to discredit this first suggested explanation. Such difference in the primary leaf system as did exist between the different subclasses was more likely the effect of chlorosis during the preceding year than the cause of chlorosis during the current season. However, the root weights are of some interest. That poor root development may predispose to chlorosis is entirely probable. In a soil deficient in available iron, a plant with little root surface would presumably be especially liable to iron hunger.

The second and third explanations are both believed to apply in part to the obvious association of chlorosis and poor development. Lack of balance of soil solution around the roots of the plant sufficient to interfere seriously with the chlorophyll-forming function might easily interfere more or less with some of the other processes in the plant to an extent sufficient to decrease growth rate. Furthermore, the shortage of chlorophyll and consequent decreased ability to synthesize carbohydrates would very naturally result in decreased growth of at least some parts of the plant. It is, therefore, the belief of the writers that poor development of roots (but not of tops) is probably a contributory cause of chlorosis, that both chlorosis and poor development of the whole plant may in part be parallel and independent results of excessive lime, and that chlorosis is almost certain to result in a still further decrease in growth. A circular relation, therefore, seems to obtain.

The data on Douglas fir in Tables III and IV indicate that with this species, as with the western yellow pine, there is a decided difference in growth between green and chlorotic seedlings. With this species as with the other, the weight of the roots of the chlorotic seedlings is much more deficient than the length. From the data it is not possible to determine separately the first and second year's growth, as was possible to a certain extent in the western yellow pine. The deficient terminal bud production and development on the part of the chlorotic plants is as evident in Douglas fir as in western yellow pine.

A condition associated with chlorosis in Douglas fir which does not appear in the measurements is its abnormally prompt loss of turgor on the cutting off of the water supply. The leaves of chlorotic seedlings wilted so quickly after the plants were taken up that measurements of the width of the leaves could not have been accurately made for this species. Another difference not shown by the measurements is in the color of the terminal buds formed. The terminal buds of normal Douglas fir are a reddish brown, while those of the chlorotic seedlings vary from a light brown to a brown.

No relation between the growth rate and the artificial supply of iron was evident from an examination of the beds. As the treatments were not begun until the latter part of the growing season, no material effect was to be expected.

SUMMARY

Chlorosis has been the most serious problem encountered in the successful production of coniferous nursery stock at a nursery in southern Idaho. The disease affects all coniferous species grown in this nursery. With chlorosis were associated poor growth of roots, stems, and leaves, failure to form normal terminal buds, and susceptibility to winter injury.

The importance of excessive soil moisture as a cause of chlorosis has not been definitely determined. Preliminary experiments indicate, however, that it is relatively unimportant.

Chlorosis in western yellow pine at the Pocatello Nursery has been definitely corrected by spraying with ferrous sulphate at 10-day intervals. Similar, though less decisive, results were obtained with Douglas fir. A 1 per cent solution in amounts sufficient to wet the tops thoroughly proved the most satisfactory treatment. A 2 per cent solution ultimately caused chemical injury to practically all the plants. In a region of more frequent rains the stronger solution might be better.

The control of chlorosis in jack pine and western yellow pine at the Morton Nursery in Nebraska by spraying with a 1 per cent solution of ferrous sulphate has given such evidence of success that it has been adopted as a part of the regular nursery practice.

The three soils on which conifers have been found decidedly chlorotic all contain considerable amounts of carbonate and have been formed, in part at least, from limestone. The nursery water supply at Pocatello also contains much calcium bicarbonate. No definite correlation could be found between chlorosis and the amounts of calcium or of carbonate obtained by hydrochloric-acid digestion analysis.

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FARMERS' BULLETIN 1123
UNITED STATES DEPARTMENT OF AGRICULTURE

GROWING AND PLANTING HARDWOOD SEEDLINGS on the FARM

FOREST TREES grown on the farm add to its value and beauty. They supply material for farm use, such as poles, posts, and cordwood; and they afford shelter for live stock, and protect crops and buildings from the hot winds of summer and the cold winds of winter. Moreover, they can often be grown successfully on soils too poor or on slopes too steep for the successful production of the ordinary agricultural crops.

It is the purpose of this publication to point out simple methods which may be followed in planting and caring for hardwood trees on the farm and in collecting, extracting, and storing the seed of the common hardwood trees of the United States and in growing the young trees in a home garden or nursery.

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester
Washington, D. C. January, 1921

GROWING AND PLANTING HARDWOOD SEEDLINGS ON THE FARM.

C. R. TILLOTSON, *Forest Examiner*.

CONTENTS.

WHAT TREES TO GROW.

IN DECIDING on the species of hardwood trees to be grown on the farm, one should keep in mind, first, the object of growing the trees, and, second, their adaptability to the climate of the region and to the situation in which they are to be planted. To illustrate: The boxelder is not a good tree to plant for lumber; yellow poplar, because of climatic conditions, can not be grown successfully in the plains region of the central United States; and hardy catalpa will not thrive on poor sandy or heavy clay soils. To a certain extent trees may be grouped as those most valuable for lumber, for posts and poles, for windbreaks, etc. An attempt has been made in Table 1 to group the hardwood trees according to their suitability for such uses. The second consideration is very important. Too often prospective planters are dazzled by tales of trees that will thrive on any and all soils, that will grow with extreme rapidity, that are imperishable when set out as posts, or that are much more valuable than other species for lumber. It is usually safe to assume that such reports have little foundation in fact. *The best trees for planting on the home farm are usually those that grow naturally on similar soils in the region* or those that have been tried out by the neighbors and have been proved a success. Many plantations have turned out to be failures, with resulting disappointment to their owners, because of the selection of trees unsuited either to the climate or to the soil of the planting site.

NOTE.—This bulletin does not represent original work by the writer. The information it contains has been compiled from numerous sources. The writer is indebted especially to Prof. J. S. Illick, of the Pennsylvania department of forestry, for considerable information and many helpful suggestions.

TABLE 1.—*Hardwood trees most valuable for various purposes.*

Lumber.	Handle stocks.	Excelsior.	Railroad ties and round mine timbers.	Cooperage stock.
Ash.	Ash.	Aspen.	Black locust.	Ash.
Basswood.	Beech.	Basswood.	Honey locust.	Basswood.
Beech.	Birch.	Cottonwood.	Red oaks.	Beech.
Birch.	Hickory.	Willow.	White oaks.	Birch.
Black cherry.	Sugar maple.	Yellow poplar.		White elm.
Cottonwood.	White oaks.			Sugar maple.
Cucumber.				White oaks.
White elm.				Red gum.
Hickory.				
Sugar maple.				
Red oaks.				
White oaks.				
Red gum.				
Sycamore.				
Black walnut.				
Yellow poplar.				

Veneer logs.	Poles and posts.	Hardwood distillation.	Windbreaks.
Basswood.	Hardy catalpa.	Beech.	Green ash.
Beech.	Coffee tree.	Black birch.	Boxelder.
Yellow birch.	Red elm.	Yellow birch.	Cottonwood.
Black cherry.	Eucalypts.	Sugar maple.	Eucalypts.
Sugar maple.	Black locust.		Hackberry.
Oaks.	Honey locust.		Silver maple.
Red gum.	Russian mulberry.		Russian mulberry.
Sycamore.	Oaks.		Osage orange.
Black walnut.	Osage orange.		Russian olive.
Yellow poplar.	White willow.		White willow.
			Yellow willow.

The planter will doubtless be influenced in his choice of species by their rates of growth. Tables 2 and 3 show this approximately for the kinds of trees for which growth figures are available. The rates indicated may be too low for some trees in some regions, but it is believed that the tables are reliable for purposes of comparison.

TABLE 2.—*Average diameter growth of hardwood trees.*

Average number of years required to grow each inch in diameter.	Species.
½ to 3 years	* Eucalypts.
2 to 4 years	* Cottonwood, black willow, * white willow,* honey locust, * black locust.
3 to 6 years	Red gum, * silver maple, *white elm, * Russian mulberry, yellow poplar, chestnut, * hardy catalpa.
4 to 7 years	* White ash, * green ash, * boxelder, * black walnut, * butternut, red oak, black oak, * bur oak, aspen, * osage orange, basswood.
5 to 10 years	Hickory, white oak, chestnut oak, paper birch, *hard maple, yellow birch, beech.

The table is based upon the growth of trees both in plantations (those starred) and in natural forest (those not starred). In plantations more rapid growth can often be secured, particularly of the trees named in the last line.

TABLE 3.—*Height growth of hardwood forest trees produced from seed.*

[Average height.[1]]

Species.	At 10 years.	At 20 years.	At 30 years.	At 50 years.
	Feet.	*Feet.*	*Feet.*	*Feet.*
Green ash	26	41	52	70
White ash	19–25	34–50	45–67	62–83
Aspen	8–21	17–40	28–55	50–75
Basswood	....	16–32	23–44	37–63
Beech	....	8–19	13–28	22–42
Paper birch	13	30	44	62
Yellow birch	....	*–30	8–39	15–54
Boxelder [2]	20	....	....	....
Hardy catalpa [2]	19	27	33	....
Chestnut	7	17	33	64
Cottonwood [3]	56	97	115	136
White elm	....	21	28	40
Eucalyptus [2] (blue gum)	24–80	70–90	85–160	....
Shagbark hickory	3– 7	8–18	15–32	32–51
Black locust	15–20	28–45	....	44–65
Honey locust [2]	18	27	35	....
Silver maple [2]	22	44	60	80
Sugar maple	....	*–18	*–29	10–48
Bur oak [2]	....	....	40	60
Red oak	13	32	46	72
White oak	11–12	22–25	32–38	53–63
Osage orange [2]	....	15–25	37	....
Red gum	35	66	88	108
Black walnut [2]	18	30	40	60
Black willow [3]	50	73	89	109
White willow [2]	15–24	35–50	....	....
Yellow poplar	20–27	36–50	50–64	78–83

*Data not available.

[1] The slower growth in each case is on poor situations; the more rapid growth, on better situations. Where only one figure is shown, it represents approximately the average growth on all situations where measurements have been recorded. In plantations, the height growth should equal and often exceed the faster rate of growth indicated by the table.

[2] Growth in plantations on farm lands.

[3] Measurements made on trees in the lower Mississippi Valley where growth is very rapid.

PLANTING TWO OR MORE KINDS OF TREES TOGETHER.

A mixture of two or more kinds of trees in a plantation may sometimes be desirable, although it is not ordinarily recommended. For their best development, some trees, such as cottonwood, should be spaced widely in a plantation; others, such as black walnut and black locust, have such scant foliage that their shade does not prevent the growth of a heavy sod of grass. In both of these cases, a mixture will more completely utilize the area planted, increasing the yield and bringing about better forest conditions in the plantation.

Mixtures may be desirable for other reasons. Planting stock of one species alone may be expensive; and if a less valuable tree, or filler, to be cut out when the trees begin to crowd, is mixed with the main crop, it will keep down the first cost. If a species to be planted is liable to serious diseases or insect attack, as are chestnut and black locust, the planting in mixture with another kind of tree not liable to such attack will provide for a stand of trees in case the chestnut or locust is killed.

The following list gives a number of hardwood mixtures which should prove successful on soils and in regions adapted to both species. It can not be stated with assurance that these mixtures will produce a satisfactory stand, because experience with them has not been sufficient to serve as a strict guide. Ordinarily, plantings of one species only are more satisfactory:

Hardwood mixtures for planting.

Cottonwood and silver maple.
Cottonwood and green ash.
Honey locust and hackberry.
Honey locust and green ash.
White elm and hackberry.
White elm and green ash.
White elm and white ash.
Black walnut and green ash.
Black walnut and hackberry.
Black walnut and hickory.
Black walnut and white oak.
Black walnut and white ash.
Black locust and yellow poplar.
Black locust and white oak.
Black locust and boxelder.
Black locust and hickory.
Yellow poplar and white oak.
Yellow poplar and hard maple.
Yellow poplar and hickory.
Red gum and white oak.
Red gum and hickory.
Red gum and beech.
Green or white ash and hackberry.
Green or white ash and hickory.
Red oak and basswood.
Red oak and white oak.
Red oak and hard maple.
Red oak and hickory.

LOCATION OF PLANTATION OR WINDBREAK.

Generally speaking, unless intended for windbreaks, plantations should be located on the poorest soil of the farm, that least suited to the production of agricultural crops. Hillsides and poorly drained or rocky or sandy situations should be selected, if there are such. Corners of the farm cut off by a stream or railroad may be chosen. If there are no such situations on the farm, the plantation should be located near the buildings, where it will not only be convenient but will serve as a windbreak.

FIG. 1.—Red oak and chestnut plantation. Strafford County, N. H.

Windbreaks for protection of the home and buildings should be located on that side of the buildings and the stock-feeding yards against which the prevailing winter winds blow. If a narrow windbreak of only a few rows is planted, it should be several rods away from the building or yard. Snow drifts under the lee of such a windbreak and lies deep around buildings or a feed lot close to it. This drifting may be partially prevented by planting two such narrow windbreaks parallel to each other and about two rods apart. Snow will then drift into and for the most part be held in this intervening space.

Windbreaks for crop protection should be located so as to protect the crop from the most damaging winds, usually summer winds. As efficient windbreaks exert their protective influence along the surface to a distance of from fifteen to twenty times their height, the intervals between them should be about fifteen or twenty times the height of the trees at their maturity.

ESTABLISHMENT OF PLANTATION.

PLANTING OF STOCK.

In starting a grove, the planter ordinarily has the choice of using seedlings, seed, or cuttings. Seedlings 1 or 2 years old are preferable in the great majority of cases. They are fairly cheap and have the best chance of succeeding.

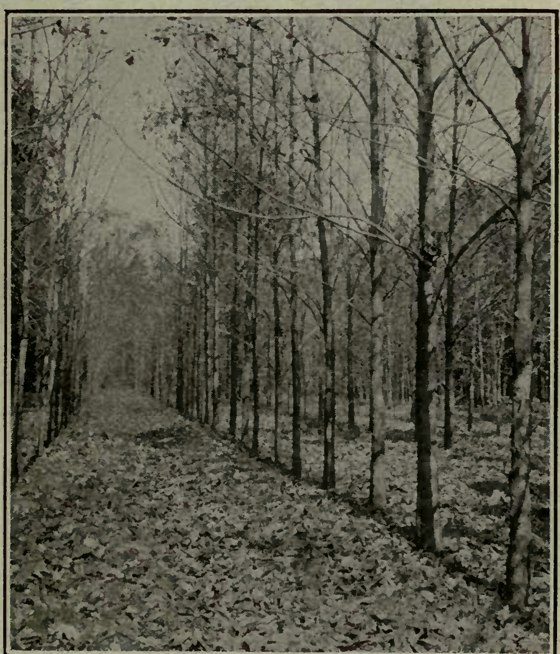

FIG. 2.—Shellbark hickory plantation, 27 years old. Champaign County, Ill.

Nut trees, such as walnut, hickory, and oak, develop a very deep taproot and few lateral feeding roots during their first year. They can not ordinarily be transplanted to the field so successfully as other trees, so that planting the nuts or acorns on the permanent site is usually considered preferable. Black walnut plantations have been successfully started by the use of sprouted nuts. It would seem that the same method might be followed with other nut trees.

Cottonwood and willow plantations are most easily started with cuttings. These are simply from 12 to 14-inch sections taken from the 1 or 2 year old twigs of living trees. The cuts should be made with a sharp tool, to avoid bruising the bark. Cuttings should be collected during early winter and buried in moist sand in a cool place until the time for planting.

PREPARATION OF SOIL.

The necessity of soil preparation will depend somewhat on the region. On the prairies or in other regions where tree growth does not naturally thrive, the area should be plowed, preferably in the fall. In regions where trees naturally thrive, such preparation, is also decidedly beneficial although not always necessary. *Heavy*

FIG. 3.—Soft maple plantation. Trees 5 to 13 inches in diameter. Jefferson County, Iowa.

sod land in any region should not be planted until it has been plowed and cropped for two or three years.

METHODS OF PLANTING AND SOWING.

SLIT.

In the slit method a wedge-shaped hole is opened in the ground by inserting a spade or mattock and moving it backward and foreward. The root of the tree, or the cutting, is then inserted back of the tool in the cleft thus formed, the tool is removed, and the earth is pressed with the foot firmly around the plant. If the root systems are not overlarge, this method may generally be used with success in light soil that is free from rocks.

INDIVIDUAL HOLES.

If the soil is heavy or rocky, or if the trees have large root systems, the best method is simply to dig a hole for each individual tree, pull the soil in over the roots, and tamp it thoroughly. This is undoubtedly the surest method for trees of large size.

PLANTING SPROUTED NUTS.

A simple and successful method of planting black walnut was discovered by a farmer in Indiana. It should be equally successful, it seems, with the oaks, hickories, butternut, or any other hardwood species which develop pronounced taproots and in consequence can not be very successfully transplanted from the nursery to the field. This farmer buried the walnuts in a shallow pit where they were subjected throughout the winter to the action of moisture and frost.

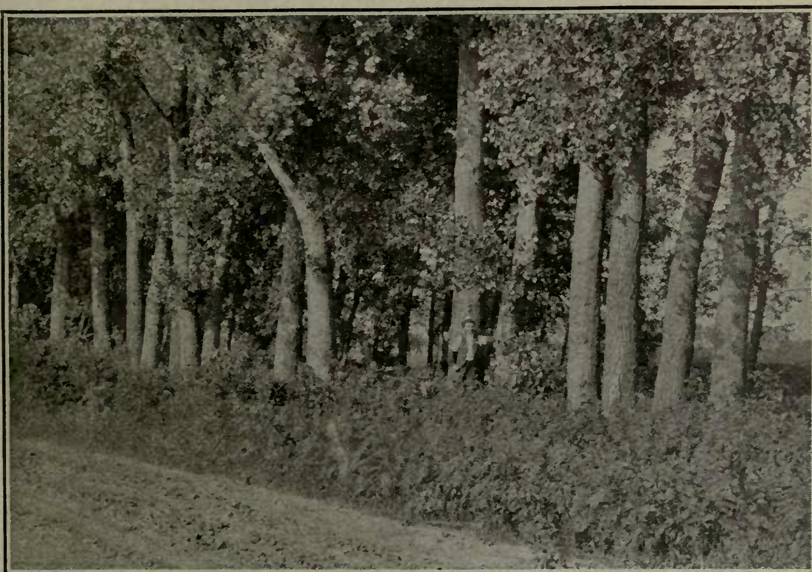

FIG. 4.—Cottonwood and green ash windbreak. Butler County, Nebr.

With the advent of warm spring weather, the nuts began to sprout. He planted the sprouted nuts on well-tilled land by scooping out a little soil with his hands, placing the nuts in the holes thus formed, and covering them lightly. In following this plan there are several precautions which should be taken: (1) The pit in which the nuts are stored should be located in a well-drained, shaded spot; (2) the nuts should be protected against destruction by rodents; and (3) they should be examined frequently in the spring so that there will be no delay in setting them out shortly after sprouting commences.

FURROW.

The young trees or seeds may be planted in a plowed furrow. This is a rapid method and usually quite successful. It is especially suitable for planting cottonwood and willow cuttings. Seedlings are set

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in the bottom of the furrow, and loose earth is pulled around the roots and tamped firmly. Cuttings are set in the furrow with the lower ends down in a slanting position. About 1 or 2 inches of the cuttings should be left extending above the surface of the ground. Soil is then pulled in and trampled firmly about them. Seeds are dropped in the furrow, several in a spot at regular intervals, and covered with 1 or 2 inches of soil.

SEED SPOT.

In the seed-spot method seed are sown directly on the planting site in spots at regular intervals. The ground in these spots is usually

Fig. 5.—Green ash plantation, 40 years old. Champaign County, Ill.

stirred somewhat with a spade or mattock, then several seed are dropped on the spot and covered to a depth of 1 or 2 inches with soil. This method is particularly suitable for fall sowing of the seed of the oaks, hickories, black walnut, and butternut.

BROADCAST SOWING.

The seed may be scattered broadcast over an area, either plowed or unplowed, in the same manner as wheat and oats are sown. This method is not recommended for any species, as it requires a large quantity of seed to the acre and is likely to be unsuccessful.

SEASON OF PLANTING OR SOWING.

In general, early spring planting is preferable to planting at any other season. As compared with fall planting, it has at least two distinct advantages: The stock has a whole growing season in which to become established before it is subjected to the rigors of winter; and it is not in immediate danger of being heaved out of the ground by alternate freezing and thawing. If there is no great danger of the seeds being disturbed by rodents during the winter, fall is the preferable season for direct sowing of the seed of nut-bearing trees and of the oaks. When this danger exists, spring sowing is advisable.

SPACING OF TREES IN PLANTATION.

If timber is the primary object of a plantation, rather close spacing is advisable. This method produces trees with straight bodies and few branches, and hence of high lumber value. If the primary object

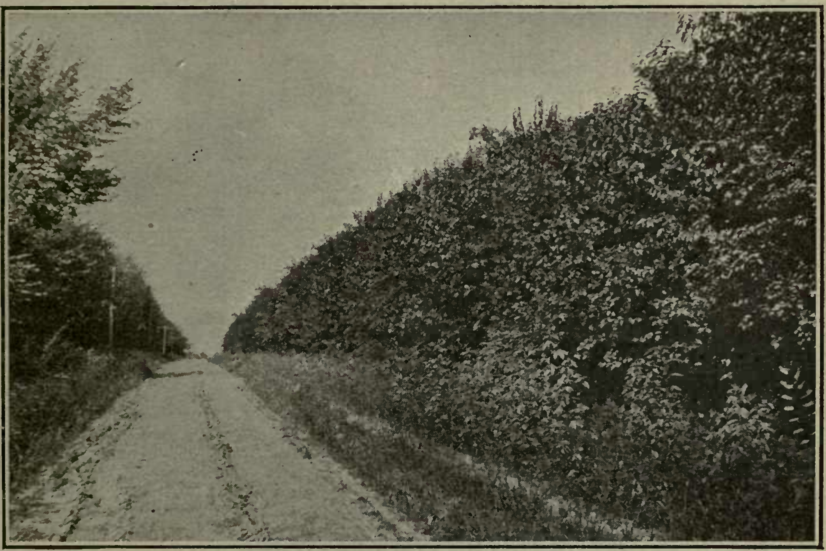

FIG. 6.—Osage orange windbreak, 12 years old. Monroe County, Iowa.

is protection, close spacing in the rows and wide spacing between them is best; for it will produce trees with some branches extending nearly to the ground, and hence will give the greatest protective efficiency. The actual spacing desirable for these two purposes depends upon the characteristics of the tree, upon the region, and upon the area or site to be planted. Trees which grow well in shade, such as hard maple and beech, may be planted more closely than those which require abundant light, such as cottonwood and yellow poplar. On situations which because of poor soil are unfavorable to tree growth, closer spacing is advisable than on more favorable situations. The greater number of trees to the acre will compensate for the higher mortality soon after they are set out, and, through the greater amount of shade furnished, will afford better protection to the soil. In regions of little rainfall there will not be sufficient moisture to support a dense grove of trees. Accordingly, very close spacing can not be practiced there unless irrigation is possible.

The approximate spacing considered generally desirable for the more promising species is shown in Table 4. To meet a specific condition of soil or climate, some other spacing may be better. Before planting, it is advisable to write to the State forester concerning the matter.

TABLE 4.—*Spacing for forest trees.*

Kind of trees.	Spacing for woodlot.	Spacing for two-row wind-break.	Kind of trees.	Spacing for woodlot.	Spacing for two-row wind-break.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Green ash	6 by 6	4 by 8	Honey locust	8 by 8	
White ash	6 by 6		Hard or sugar maple	6 by 6	
Basswood	6 by 6		Silver maple	6 by 8	4 by 8
Black birch	6 by 6		Russian mulberry		4 by 8
Yellow birch	6 by 6		Red oak	6 by 6	
Boxelder		4 by 8	White oak	6 by 6	
Hardy catalpa	7 by 7		Osage orange		2 by 8
Black cherry	6 by 6		Red gum	8 by 8	
Cottonwood	10 by 10	4 by 10	Sycamore	8 by 8	
White elm	6 by 8		Black walnut	6 by 8	
Eucalyptus (blue gum)	10 by 10	4 by 10	Yellow poplar	10 by 10	
Hickory	6 by 6		White willow	8 by 8	3 by 8
Black locust	6 by 6		Yellow willow	8 by 8	3 by 8

Table 5 shows the number of trees required to the acre for the spacings given.

TABLE 5.—*Trees required to the acre with spacing indicated.*

Spacing in feet	10 by 10.	8 by 8.	6 by 8.	6 by 6.	4 by 8.	4 by 6 or 3 by 8.	4 by 4 or 2 by 8.
Number of trees required to the acre.	436	680	908	1,210	1,361	1,732	2,723

CARE OF PLANTATION.

CULTIVATION.

Though cultivation is not absolutely essential in all cases, particularly on loose soils in the regions where hardwoods thrive naturally, it is nearly always beneficial to a plantation, and especially so during the first several years of its existence. Cultivation is essential to success in regions of little rainfall where irrigation can not be practiced and on areas heavily sodded with grass. A heavy sod practically insures the failure of a young hardwood plantation. Horse cultivation is entirely practicable. If desired, some agricultural crop, such as potatoes, may be grown between the rows of trees during the early period of the plantation's growth. Cultivation should be given two or three times a year.

Forest trees are subject to damage by heavy frosts and, if they are growing vigorously when these frosts occur, they may be severely injured. Late cultivation induces late growth; there should be no cultivation, therefore, after the middle of the growing season.

CLEANING AND LIBERATION CUTTINGS.

When a piece of cut-over land is planted, it may happen that the natural brushy growth present will for a few years outgrow the planted trees, overtop them, or crowd them so as to interfere seriously with their development. In such a case, it will be necessary, perhaps for two or three successive years, to lop off this brush with a knife, pruning shears, or other sharp instrument.

When there are old trees with wide-spreading crowns on areas to be planted, it will be desirable to remove these trees a few years

FIG. 7.—Russian mulberry windbreak, 5 years old. Graham County, Kans.

after the small trees are set out. Otherwise, because of the shade, the small trees will not develop satisfactorily.

THINNING.

To produce clean-bodied timber, close spacing is desirable. When the tops of the trees begin to intermingle and crowd each other, however, they become like an overcrowded stand of vegetables in a garden. Growth is stagnated. A good gardener would pull out a portion of the vegetables in a garden that had reached this condition. When trees have reached a similar condition some of them should be cut out. In both cases, the result is the best development of the remaining portion rather than a poor development of the original number. The best-formed, most valuable, and most healthy trees should be selected to remain, and the others that are likely to interfere with their growth should be removed.

Thinnings are usually necessary by the time a plantation reaches the age of 20 years, sometimes sooner. Thinning may be done at odd times by the owner of the plantation at no other cost than his labor. Care should be exercised that the openings in the crown

FIG. 8.—Cottonwood plantation, 12 years old. Trees 8 inches in diameter, 50 feet in height. Faribault County, Minn.

cover of the stand made by removing trees are no larger than may be closed in from three to five years by the growth of the remaining tree tops. When poles are cut for some farm use, a crude form of thinning may be secured by a little care in the selection of trees with a view to the betterment of the stand.

PRUNING.

Pruning of the branches of trees in a plantation is usually unnecessary and, because of the cost of the labor involved, undesirable. If spaced closely enough, most forest trees in plantations will prune

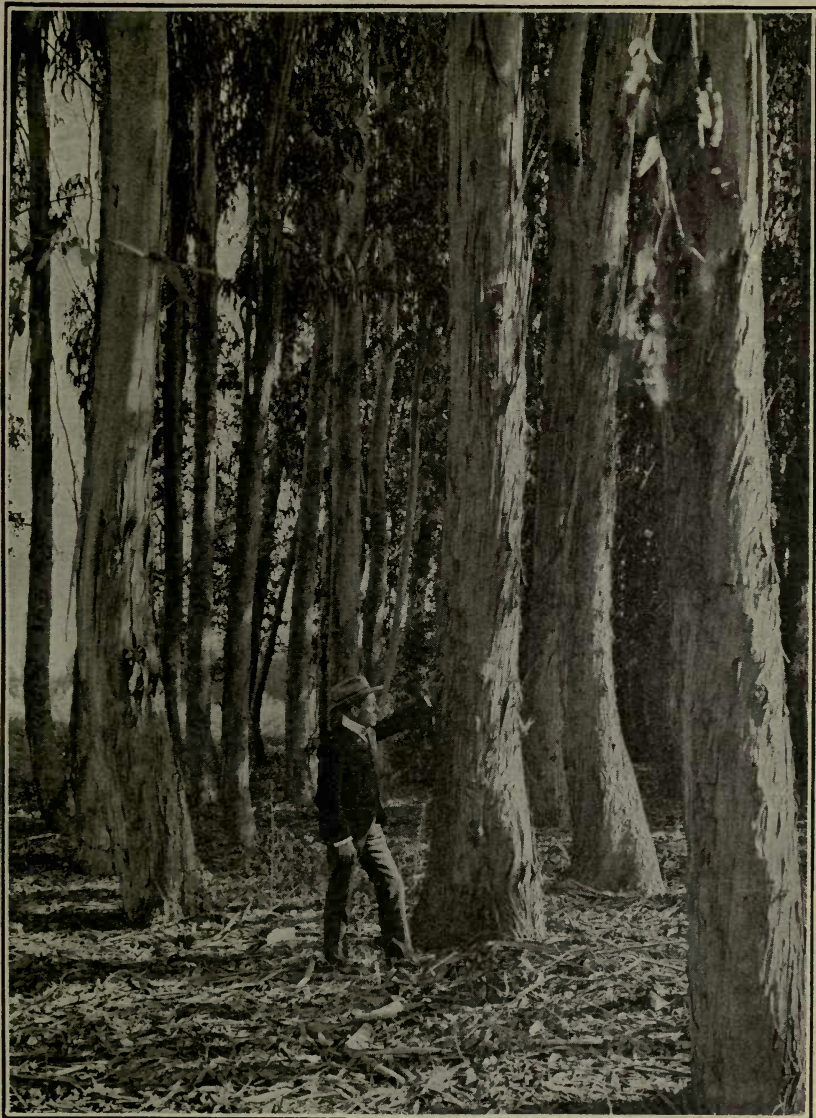

FIG. 9.—Blue gum (*Eucalyptus globulus*) plantation, 28 years old. Trees 14 inches in diameter. Los Angeles, Calif.

themselves. Sometimes it will be profitable, in a stand that is intended to produce lumber, to prune the best trees by simply knocking off with an ax such dead and brittle limbs as can be reached.

Occasionally, dead branches of black walnut trees persist for a number of years, and they are likely to form loose knots. The same is true of catalpa, which, moreover, is subject to serious attack by a fungus around the base of these loose dead branches. Such branches of both species should be removed. If, because of wide spacing or for some other reason, the trees are assuming a poor timber form, it may be necessary to correct the condition by pruning.

If pruning is undertaken it should be conducted during late winter or early spring, and should not be overdone.

If a tree is pruned too far up, it may become top-heavy and be easily broken off by a severe wind. Catalpa, ash, and black cherry

Fig. 10.—Blue gum (*Eucalyptus globulus*) windbreak, sheltering a lemon orchard. San Bernardino County, Calif.

in plantations are known to have suffered from this, and it seems likely that the same thing is true of many other species.

PROTECTION.

Plantations should be protected against fires and grazing. Fires will kill young trees and injure old ones. Live stock of all kinds should preferably be excluded from a plantation at all times and particularly when the trees are small. The animals almost invariably cause damage to the trees by nipping off the branches, peeling the bark, trampling the roots, or trampling the small trees themselves. If the shade of the trees is a necessity for the animals, they should at least be restricted to a limited area of the plantation. In case the trees are being injured by insects, animals, or diseases, a remedy should be sought by inquiry of the United States Department of Agriculture or the State Agricultural College.

SOURCES OF PLANTING STOCK.

Private nurserymen are usually able to supply planting stock of the more important forest trees. The Forest Service will supply lists of these nurserymen upon request. In the following States forest tree nursery stock of some species for forest (not landscape) planting within the State may be obtained through the service indicated.

Sources of forest tree stock.

Idaho	School of Forestry, Moscow, Idaho.
Kansas	Fort Hays Experiment Station, Hays, Kans.
Kentucky	Commissioner of Agriculture, Frankfort, Ky.
Maine	State Forest Nursery, Orono, Me.
Maryland	Maryland State Board of Forestry, Baltimore, Md.
Massachusetts	State Forester, Boston, Mass.
Michigan	State Forester, Grayling, Mich.
Michigan	Michigan Agricultural College, East Lansing, Mich.
Montana [1]	Mandan Experiment Station, Mandan, N. Dak.
New Hampshire	State Forester, Concord, N. H.
New York	Conservation Commission, Albany, N. Y.
North Dakota [1]	Mandan Experiment Station, Mandan, N. Dak.
North Dakota	State School of Forestry, Bottineau, N. Dak.
Ohio [2]	State Forester, Wooster, Ohio.
Pennsylvania	Pennsylvania Department of Forestry, Harrisburg, Pa.
South Dakota [1]	Mandan Experiment Station, Mandan, N. Dak.
Vermont	State Forester, Montpelier, Vt.
Virginia	State Forester, University, Va.
Wisconsin	Conservation Commissioner, Madison, Wis.
Wyoming [1]	Mandan Experiment Station, Mandan, N. Dak.

SEED COLLECTION, EXTRACTION, AND STORAGE.

SEED COLLECTION.

Nearly any kind of tree seed can be bought from commercial seed houses, but often it may be cheaper and otherwise more advantageous to collect it near home. The collected seed will certainly be fresh, and the seedlings grown from it should be perfectly hardy so far as the climate is concerned.

TIME TO COLLECT.

Seed should be collected when ripe. For most kinds this means during autumn. Collecting may be extended into the winter for

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[1] The Mandan Experiment Station furnishes stock only to residents of eastern Montana and Wyoming and western North and South Dakota.

[2] Nursery stock is distributed in Ohio only for demonstration or experimental purposes.

such species as the ashes, catalpa, honey locust, sycamore, and any others that retain the seed on the trees until that time. A few kinds of seed ripen during the spring or summer and must, of course, be collected at that time. Seed of such species as willow and cottonwood, which scatters soon after ripening, must be gathered promptly. Seed which hangs on the tree for a considerable period, such as that of ash and sycamore, may be gathered more at leisure.

TABLE 6.—*Seed which ripens in spring or summer.*

Species.	Time of ripening.[1]
Elms (all species except cedar elm and southern red elm)	March to June.
Silver maple	April, May.
Red maple	April to June.
River birch	May, June.
Willows	March to June.
Poplars	April to July.
Mulberry	June to August.
Cherries	June to September.
Plums	July to September.

[1] As indicated by the dates, the time of ripening for any one species varies in different regions. In the South the ripening may occur in March, while in the cooler northern regions it may be deferred until June.

WHERE TO COLLECT.

Middle-aged trees growing in the open, in fence corners, or along roadsides, and with broad-spreading crowns ordinarily produce seed in greater abundance than those growing in dense forests. Trees of this kind, when they are of vigorous growth, are among the best sources of seed. On areas where trees are being felled for lumber or other uses splendid opportunities are often afforded for seed collecting. When the trees are felled, seed borne in their tops is easily gathered.

HOW TO COLLECT.

Tree seed must necessarily be picked by hand. Seed of the oaks, hickories, walnut, beech, chestnut, often that of the locust, and sometimes that of other species, may be gathered from the ground. The seed of such trees as the ashes, cherries, cottonwood, willow, hackberries, sycamore, and basswood, which clings to the branches, is picked from the standing trees or from those felled in lumbering operations. Pruning shears on a long pole or a home-fashioned iron hook, sharpened on its inner edge and fastened to a long pole, may often be used to advantage in clipping the seed from standing trees. Sometimes, with the aid of a hook or a rope thrown over a branch, the seed may be pulled down within reach. Professional seed gatherers often climb the trees to reach the seed.

SEED EXTRACTION.

The fruit of some hardwood trees requires special treatment to separate the seed from the fleshy covering, pod, or hull.

The fruit of osage orange, mulberry, the cherries, cucumber, holly, black gum, Kentucky coffeetree, honey locust, and others of a fleshy nature, needs to be macerated in water until the seed can be washed out. It should then be dried in a cool, shady place.

The fruit of the black locust readily yields its seed if it is placed in a sack or on a smooth surface and lightly flailed.

When fairly dry, the hulls of the pignut, shellbark, shagbark, and the mockernut hickories will fall off in handling. The thin hulls of other hickories need not be removed. The soft hulls of black walnut may be removed by hand, by running the nuts through a close-set

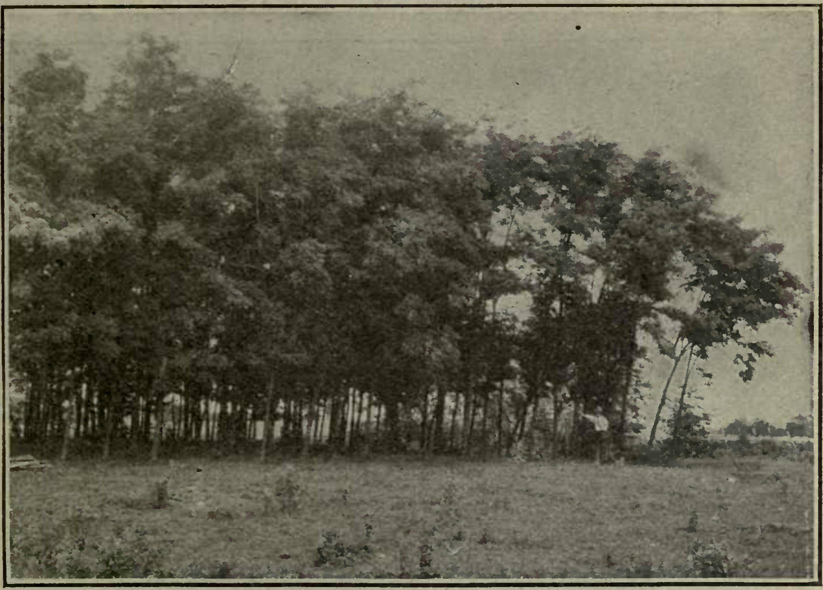

FIG. 11.—Black locust plantation, 9 years old. Trees 3 to 6 inches in diameter, 35 feet in height. Knox County, Ind.

cornsheller, or by allowing the nuts to lie on the ground in a sheltered place until the hulls rot or are destroyed by a small maggot that often attacks them. This maggot does no harm to the nut itself.

SEED STORAGE.

The best time to sow seed, either in the nursery or on the permanent planting site, is soon after it is ripe. When this is not possible, the seed must be stored until spring. Seed that matures in the spring and early summer, that of the willows, poplars, most of the elms, river birch, and red and silver maples, does not retain its vitality well if stored. It should be sown as soon after ripening as possible. Most of the late-maturing hardwood seed may be successfully stored until the following spring.

The principal considerations regarding seed storage are that the seed must not be allowed to dry out excessively, because this impairs its power to germinate; and that it must not be kept at the same time moist and warm, because this induces premature germination, or molding and deterioration. Seed should not be stored in a warm place. Cold storage of some kind is essential.

COLD DRY STORAGE.

Some kinds of hardwood tree seed may be stored dry without deteriorating greatly, provided the temperature is constantly near the freezing point or lower. Among such is the seed of the catalpa,

FIG. 12.—Red mahogany (*Eucalyptus resinifera*), 11 years old. Trees 14 to 18 inches in diameter, 60 to 65 feet in height. Brevard County, Fla.

honey locust, osage orange, and boxelder. After the seed coat is thoroughly dried by exposure to the air for a few days, the seed may be placed in sacks and hung up out of the reach of rats, mice, squirrels and chipmunks, in some outbuilding or in the attic where the temperature will remain low through the winter.

COLD MOIST STORAGE.

Cold moist storage is probably the most suitable for all kinds of hardwood tree seed, provided the temperature can be kept at the freezing point or lower. Even seed that can be stored dry will, if stored under cold moist conditions, germinate more quickly when sown. Cold moist storage is particularly well adapted for the seed of walnut, oaks, hickories, chestnut, beech, basswood, sugar maple, and some other trees, the seed of which does not keep well if stored dry. If a large quantity of the nut seed is to be stored, it may simply be thrown on the ground after the advent of cold weather, in a layer 2 or 3 inches deep, and covered with sand, leaves, or forest litter, and then with a layer of dirt. The dirt should be rounded off so that water will not stand on it, and the whole pile may be covered with boards to prevent the soil from being washed away. It may be preferable to dig a shallow pit 6 inches or more in depth, in which to place the seed, and then use the same method of covering. In either case, the situation selected should be such that water will not collect and stand upon the pile.

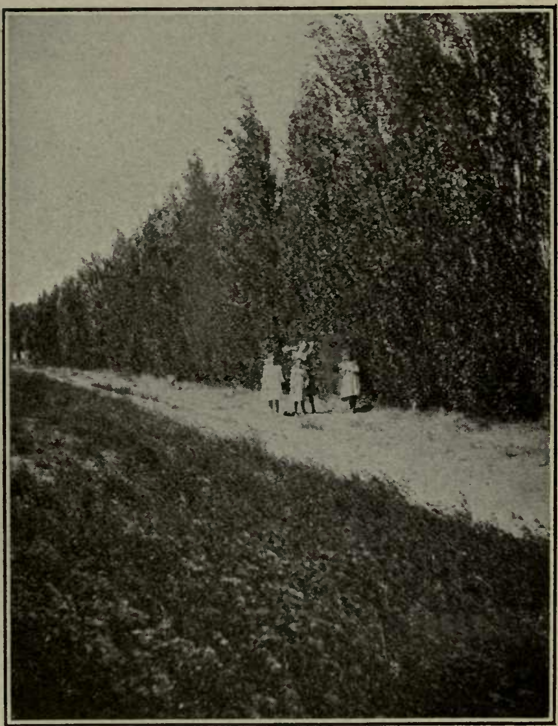

FIG. 13.—Lombardy poplar windbreak, 11 years old, 30 feet high. Finney County, Kans.

When there is only a small quantity of seed, or when the seed itself is rather small, it may be stored in a box of moist sand. First, a layer of sand about 1 inch deep should be put in the box, then a layer of seed 1 inch thick, another layer of sand, and so on until the box is full. The box should be buried out of doors, at a depth of a foot or more, and covered with leaves and soil. A well-drained location should be chosen. In the spring the sand may be separated from the seed by screening. Very small seed, such as that of birch, may be placed loose in small cloth sacks and these alternated with layers of sand.

Seed stored in any one of these ways should be examined occasionally to see that it is not being disturbed by rats or mice. It must be watched very carefully in the spring, for, with the coming of warm weather, it is likely to germinate or to mold and heat. It must be sown either in the nursery or in the field at the very earliest possible opportunity after the frost is out of the ground in the spring.

Possibly the chief objection to both of these methods of storage out of doors is that most kinds of seed can be kept over only one winter, because with the coming of warm weather, the seed will begin to sprout. The seed of a few trees, however, such as the hawthorns, hollies, and black walnut, often does not germinate readily the next spring. This seed may be stored in moist sand in a cool place even until the second spring.

TABLE 7.—*Method of storage suitable for different kinds of tree seed.*

Cold and dry.[1]	Cold and moist.	Can not be stored; should be sown at once.
Birches.	Alder.	River birch.
Black locust.	Ashes.	Blue beech.
Boxelder.	Basswood.	Elms (except cedar elm and southern red elm).
Catalpa.	Beech.	Ironwood.
Black cherry.	Black gum.	Red maple.
Holly.	Black walnut.	Silver maple.
Honey locust.	Butternut.	Poplars.
Kentucky coffeetree.	Chestnut.	Willows.
Mulberry.	Cucumber.	
Osage orange.	Dogwood.	
	Cedar elm.	
	Southern red elm.	
	Hackberry.	
	Hawthorn.	
	Hickories.	
	Sugar maple.	
	Oaks.	
	Persimmon.	
	Red gum.	
	Sycamore.	
	Yellow poplar.	

[1] While the species listed in this column will withstand cold and dry storage, cold and moist storage would be preferable for most of them.

GROWING THE SEEDLINGS.

While some hardwood seedlings may be grown without great difficulty, the production of others, such as the eucalypts, should be left to the professional nurseryman. If a man's time and the actual expense connected with growing hardwood seedlings are considered, it may often be no cheaper to grow than to buy them. When home-grown, however, the seedlings are at hand when wanted, and this is a distinct advantage.

LOCATION OF SEED BEDS.

The seed beds should be located in good, well-drained, preferably loamy soil, in any convenient place. Proximity to woods or brushy areas should ordinarily be avoided, because these places harbor mice, chipmunks, or squirrels, which may disturb the seed. Proximity to the farm dwelling is desirable, because rodents are less likely to be abundant there.

PREPARATION OF SEED BEDS.

As with beds for vegetable crops, the soil should be spaded or plowed up and then well pulverized with harrow or rake. The smaller the seed to be sown the more thorough should be the preparation of the soil. Fall plowing, followed by spring spading and raking, will result in the soils being more mellow than if spring spading and raking only are practiced. Thorough preparation of the beds will result in better germination of the seed and better growth of the seedlings.

SOWING THE SEED.

METHOD.

Although in commercial operations the practice of broadcasting hardwood seed of many species is often followed, it is believed that in a small farm nursery it will ordinarily be more satisfactory to sow most kinds of seed in drills. These drills may be 2 or 3 feet apart to permit horse cultivation, or they may be spaced as closely as 10 or 12 inches. In the latter case, hand cultivation will be necessary. Those trees which may need shade (p. 27) should be grown in closely spaced rows. Less work and expense will then be entailed in providing the shade than is necessary when the rows are 2 or 3 feet apart.

FIG. 14.—Hardy catalpa plantation, 21 years old. Iowa County, Iowa.

The seeds should be sown at a depth equal to two or three times their own thickness and close enough in the drill so that from 12 to 15 seedlings to the linear foot will result. Ordinarily, the drill need not be more than half an inch wide. In some cases, however, a drill of that width will result in crowding the seed. This is true for the seed of yellow poplar, only a small proportion of which sprouts (see Table 7); for seed with large wings, such as that of maples, catalpa, and ashes; and for seed of large size, such as that of walnut, butternut, chestnut, and some of the oaks. In all such cases the drills should be 2 or 3 inches wide, or wider if necessary, so that the seed may be distributed in them without crowding.

With small or thin seed, such as that of birch, elm, or sycamore, the best results, perhaps, will be secured by sowing broadcast and rather thickly over the beds, pressing the seed into the loose soil by means of a board, and covering it very lightly with soil and a light mulch of leaves or straw. Nearly any seed may be broadcasted, if that is desired.

THE USE OF SPROUTED SEED.

Because of the long taproot formed by the nut-bearing trees, and the consequent loss that ordinarily attends the transplanting of seedlings to the field, an experiment conducted by the Pennsylvania Forest Commission is of interest. Seed of white oak, black walnut, butternut, hickory, and red ash was stored over winter and stratified thinly in the spring. After the seed began to germinate and the root had developed to a length of from 2 to 4 inches, from 1 to 2 inches of this was pinched off. When the seed was planted, a very fibrous, stocky root system developed, the usual long taproot being absent.

NUMBER OF SEED TO SOW.

The number of seed to sow per foot depends upon the percentage of germination. This varies considerably, but Table 8 shows approximately the proportion for different species.

TABLE 8.—*Number of seed to sow per running foot of row to secure 15 seedlings to the foot.*

Kind of tree.	Proportion of seed that will sprout.	Number of seed to sow to the foot.	Kind of tree.	Proportion of seed that will sprout.	Number of seed to sow to the foot.
Yellow poplar	$\frac{1}{10}$	150	Honey locust	$\frac{7}{10}$	23
Sycamore	$\frac{3}{10}$	50	Oaks	$\frac{7}{10}$	23
Basswood	$\frac{1}{2}$	30	Beech	$\frac{3}{4}$	20
Maple	$\frac{1}{2}$	30	Black walnut	$\frac{3}{4}$	20
Mulberry	$\frac{1}{2}$	30	Butternut	$\frac{3}{4}$	20
Ash	$\frac{3}{5}$	25	Hardy catalpa	$\frac{3}{4}$	20
Boxelder	$\frac{3}{5}$	25	Black cherry	$\frac{3}{4}$	20
Kentucky coffeetree	$\frac{3}{5}$	25	Chestnut	$\frac{3}{4}$	20
Red gum	$\frac{3}{5}$	25	Hackberry	$\frac{3}{4}$	20
Black locust	$\frac{7}{10}$	23	Hickory	$\frac{3}{4}$	20
Elm	$\frac{7}{10}$	23	Osage orange	$\frac{3}{4}$	20

In the case of yellow poplar, for instance, which has a germination of only 10 per cent, it would be necessary to sow 150 seeds to the foot to obtain 15 seedlings. Only 50 seeds to the foot would be necessary for sycamore, which has a germination of 30 per cent.

The number of seeds to the pound of the more important species is about as follows:

TABLE 9.—*Approximate number of seed to the pound.*[1]

Kind of tree.	Number of seed to the pound.	Kind of tree.	Number of seed to the pound.
Arizona ash	13,000	Hackberry	2,600
Blue ash	7,000	Bitternut hickory	110
Green ash	16,000	Mockernut hickory	110
White ash	6,000	Pignut hickory	200
Basswood	6,000	Shagbark hickory	90
Beech	1,400	Shellbark hickory	80
Black or sweet birch	488,000	Honey locust	3,000
Yellow birch	425,000	Kentucky coffeetree	230
Paper birch	700,000	Red maple	18,000
Black gum	2,800	Silver maple	2,400
Black locust	27,000	Sugar maple	7,200
Black walnut	25–35	Russian mulberry	200,000
Boxelder	14,500	Chestnut oak	180
Butternut	16–40	Pin oak	380
Hardy catalpa	19,500	Red oak	125
Black cherry	4,500	Scarlet oak	260
Chestnut	100–150	Swamp white oak	160
Cottonwood	1,350,000	White oak	210
Cucumber	3,000	Osage orange	12,500
Red elm	54,000	Red gum	175,000
White elm	94,000	Sycamore	170,000
Eucalyptus (blue gum)	215,000	Yellow poplar	18,500

[1] Includes that portion of the fruit which is generally sown.

SEASON TO SOW.

Seed which ripens in the spring or early summer (see Table 1) should be sown at that time. That which ripens in the autumn may be sown then, or stored until spring. Fall sowing is in most regions preferable for all species, if the seed beds can be adequately protected against rodents. It is especially true for such seed as that of the chestnut or the white oaks, which may lose their vitality if stored over winter. Fall sowing should be deferred until just before cold weather sets in. If seed is sown early in the fall, and warm weather follows, the seed may sprout and later be killed by the cold of winter. Spring sowing should be done just as soon as the frost is out of the ground.

It is generally advisable to mulch fall-sown seed beds with 2 or 3 inches of forest leaves or litter. Straw may also be used. This mulch will prevent the rains from washing out the seed and will also prevent the ground from alternately freezing and thawing, and heaving out the seed. The mulch should be removed as soon as the seedlings begin to appear in the spring.

METHODS OF HASTENING THE GERMINATION OF SEED.

Seed coats which are nearly impermeable to water are often the cause of delay in sprouting. Fall sowing, or the cold moist storage of the seed over winter, gives a long period for absorbing moisture. The seed will then usually sprout promptly the following spring or summer. Sprouting is sometimes hastened by soaking the seed for several days in *cold* water. If stored dry and intended for sowing in the spring, the bony-coated seed of black locust, honey locust, and Kentucky coffeetree, just before sowing, should be placed in water heated nearly to the boiling point. After the seed has swollen, it should be removed and sown at once. The operation should be repeated for the seed which does not swell on the first immersion.

FIG. 15.—Black walnut plantation. Indiana.

LENGTH OF TIME REQUIRED FOR SPROUTING.

Some seeds sprout in a few days, others not for several weeks, and still others often not until the second season, particularly if they are stored dry over winter and then sown in the spring. Among those which are likely to lie over for a year are basswood, holly, black locust, Kentucky coffeetree, and honey locust. If stored dry and sown in the spring, a portion of the seed of some trees may sprout the first year and an additional portion the following year. Among these are hackberry, blue beech, ironwood, cucumber, black walnut, beech, osage orange, black cherry, white ash, boxelder, cucumber tree, yellow poplar, sycamore, and sugar maple.

CARE OF SEED BEDS.

WATERING.

If water is available and can easily be applied, it is advisable to keep the seed beds moist until the seeds sprout, and later to water the seedlings when the beds become dry. It will usually be unnecessary to water seed sown in the fall. Such seed will absorb moisture during the winter and with the coming of warm spring weather will sprout quickly. Watering of the seedlings should be discontinued after midsummer, in order that they may harden up properly before the fall frosts.

PROTECTION.

Seed beds must, of course, be protected against live stock and sometimes against field mice or other rodents. Two or three house cats usually afford some protection against the latter, but sometimes resort must be had to small traps. If birds become troublesome they must be scared away or shot.

SHADING.

Seedlings of most hardwood trees will need no shade in the seed beds; but those of the beech, birch, red gum, white ash, sugar maple, slippery or red elm, hackberry, and mulberry, are likely to be damaged by intense sunlight, and, when this appears to be the case, should be supplied with partial shade. A covering of brush or tree branches in leaf will usually be sufficient. If this is lacking, shade frames of some kind that will cut off about half of the sunlight from the seedlings should be constructed. Some nurserymen use shade frames made by nailing lath spaced about 1½ inches apart on a rectangular frame. The growing of such seedlings under somewhat open woods should prove successful.

WEEDING AND CULTIVATION.

The beds should be weeded and cultivated several times during the growing season. Horse cultivation may be practiced where the rows are spaced widely. In beds seeded broadcast cultivation is, of course, impracticable.

REMOVING SEEDLINGS FROM SEED BEDS.

Hardwood seedlings 10 inches or more in height are large enough for field planting. Most of them reach this size in one growing season. Some, including the seedlings of black cherry, cucumber tree, yellow poplar, basswood, sugar maple, red gum, black gum, red mulberry, birch, and beech, may have to remain in the seed beds two years or more. In digging them from a farm nursery the spade is the most effective tool. Care should be taken to injure the roots as little as possible, and to secure practically all of them. Injured portions of the roots should be cut off with a sharp knife. The seedlings should not be dug until the time for planting them in their permanent locations. Digging them and exposing the roots to the air for some time may kill them. Even when they are being transported to the planting site, the roots should be covered with wet burlap, wet straw, moss, or other similar material.

SOURCES OF INFORMATION AND ADVICE FOR THE PLANTER.

Many of the States now have forestry departments. A few have forest extension specialists. The men connected with the work are familiar with local conditions, and are able and willing to answer inquiries concerning planting or other forestry problems from people residing in the State. In some cases they can arrange to visit a farm and give advice on the ground. The addresses of these forestry departments or officers follow:

Sources of information concerning tree planting.

Alabama	State Commissioner of Forestry, Montgomery, Ala.
California	State Forester, Sacramento, Calif.
Colorado	State Forester, Fort Collins, Colo.
Connecticut	State Forester, New Haven, Conn.
Georgia	Forestry Department, Georgia State College of Agriculture, Athens, Ga.
Idaho	State Land Commissioner, Boise, Idaho.
Idaho	School of Forestry, Moscow, Idaho.
Indiana	State Board of Forestry, Indianapolis, Ind.
Iowa	State Forestry Commission, Des Moines, Iowa.
Iowa	Forestry Department, Iowa State College of Agriculture, Ames, Iowa.
Kansas	State Forester, Manhattan, Kans.
Kentucky	Commissioner of Agriculture, Frankfort, Ky.
Louisiana	Superintendent of Forestry, Conservation Commission, New Orleans, La.
Maine	Forest Commissioner, Augusta, Me.
Maryland	Maryland State Board of Forestry, Baltimore, Md.
Massachusetts	State Forester, Boston, Mass.
Michigan	State Forester, Grayling, Mich.
Michigan	Forestry Department, Michigan Agricultural College, East Lansing, Mich.
Minnesota	State Forester, St. Paul, Minn.
Montana	State Forester, Helena, Mont.
New Hampshire	State Forester, Concord, N. H.

New Jersey.......State Forester, Trenton, N. J.
New York.......Superintendent of Forests, Conservation Commission, Albany, N. Y.
North Carolina...Forester, Geological and Economic Survey, Chapel Hill, N. C.
North Carolina...Forest Extension Specialist, North Carolina College of Agriculture and Mechanic Arts, West Raleigh, N. C.
North Dakota....State Forester, Bottineau, N. Dak.
Ohio.............State Forester, Wooster, Ohio.
Oregon..........State Forester, Salem, Oreg.
Pennsylvania.....Pennsylvania Department of Forestry, Harrisburg, Pa.
Rhode Island.....Commissioner of Forestry, Chepachet, R. I.
South Dakota....Forest Supervisor, Commissioner of Schools and Public Lands, Custer, S. Dak.
Tennessee........Forester, State Geological Survey, Nashville, Tenn.
Texas............State Forester, College Station, Tex.
Vermont..........Chief Forester, Montpelier, Vt.
Virginia.........State Forester, University, Va.
Washington.......State Forester, Olympia, Wash.
West Virginia....Forest, Fish, and Game Warden, Philippi, W. Va.
Wisconsin.........Conservation Commissioner, Madison, Wis.

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BEAUTIFYING THE FARMSTEAD.

F. L. MULFORD,
Landscape Gardener, Office of Horticultural and Pomological Investigations.

CONTENTS.

NEED OF BEAUTIFYING THE FARMSTEAD.

HOMES are the foundation of a nation. With clean, attractive, pure homes the youth become strong, upright, honorable citizens. Anything that will make the home better will tend to improve citizenship.

The essentials of a good home are a man and woman resolved by their mutual efforts to make this world a better place in which to live and a structure that will protect life and health from undue exposure to the elements. (Fig. 1.) If the dwelling is to be really a home it must be more than a place at which to eat and sleep. (Fig. 2.) It must be for the mature a haven of rest from vexations incident to breadwinning and other serious duties of life and for the young a retreat for the solution of life's problems. Inspiration to better living must be there, incentive to strive diligently for the highest ideals; and to attain these ends, not only must the physical needs of the family be supplied moderately well but the home must be attractive. (Fig. 3.)

The foundation of this attractiveness is love among the members of the household, combined with a right moral, mental, and religious attitude. This attitude may be greatly altered by changed surroundings. Sufficiency of food and exercise with other physical comforts in moderation are conducive to the highest development,

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while marked deficiency or excess of physical comforts is debilitating. Beauty in every form has an influence for good. Forms of beauty differ greatly in their effect on persons. Children especially are wonderfully affected for good or ill by their surroundings. The greatest influences are probably seldom realized at the time they are exerted.

It is important that the home should be carefully arranged so as to give the most helpful influences. This is well recognized in cities

FIG. 1.—A structure that will afford protection from undue exposure to the elements.

and towns so far as it relates to the arrangement and decoration of the interior of houses, to some extent to the house itself, and to a less degree to its surroundings. The purpose of this bulletin is to suggest the importance of improving the surroundings of farm homes and to show how unattractive conditions (fig. 2) may be made attractive (fig. 3) without undue labor or expenditure.

The poor taste and judgment shown in developing the outward appearance of our homes have left much to be desired. In the colonial days and the early days of the Republic the prevailing style of architecture and planting in both city and country was simple, direct, and attractive. (Fig. 4.) This may have been the result of necessity or the exercise of good taste, probably the latter, in an honest endeavor to meet recognized needs by the most direct methods.

FIG. 2.—A comfortable place to eat and sleep, but not all a home should be. Compare with figure 3.

More recently, styles in city and suburban buildings have changed almost as rapidly as styles in clothing. Apparently the prevalent idea has been to make as much show as possible with the funds at

FIG. 3.—The building shown in figure 2 made homelike and attractive by suggested plantings.

command, with little regard to the real purpose to be served. What is more, the planting of trees, shrubs, and flowering plants has been largely neglected, and city and suburban styles have been copied on the farms whether appropriate or not. (Fig. 5.) Now, however, there is an evident effort to make the style of building harmonize with its needs and location.

The attention attracted by properly located, well-arranged building with good plantings is itself evidence of the extent to which these matters have been neglected in all parts of the country. Much thought and money have been expended to provide luxuriously for the physical needs, even to an extent that is harmful rather than beneficial. Little thought has been given to external appearance beyond a show to the community for the money spent.

The application of good taste in beautifying the interior of the home has been more in evidence. Attractive and homelike interiors

FIG. 4.—A colonial farmhouse.

have been common both in city and country in spite of repeated waves of fashion in interior decoration and inappropriate exteriors.

The efforts of women to make the homes attractive usually include the immediate surroundings of the dwelling. In suburban communities and in cities which are not too closely built up, men are cooperating more and more actively in the development of home grounds and often take the initiative. On the farms the little attention that is given this matter is often contributed solely by the women of the household.

In cities and villages the home and the business are so separated both in place and in character that if the man comes home from his day's labor and puts thought and work on his home surroundings it is a positive relaxation and recreation. On the farm the business and the home are so intertwined and so close together and the character of the day's labor and of the effort to beautify the home surroundings are so nearly parallel that there is not the same relaxation or recreation in the effort. The very closeness of physical relationship between the business and the home make it all the more necessary that the preeminence of the home shall be emphasized in every way possible. If this is not done business will crowd out the home spirit and make life one round of drudgery.

The farm family, because of its comparative remoteness from the turmoil and distractions of the city, has wonderful opportunities to make a real home, while the city family, with its greater temptations to dissipate its energies, has to exercise much restraint to accomplish the same end. Among the opportunities of the farm

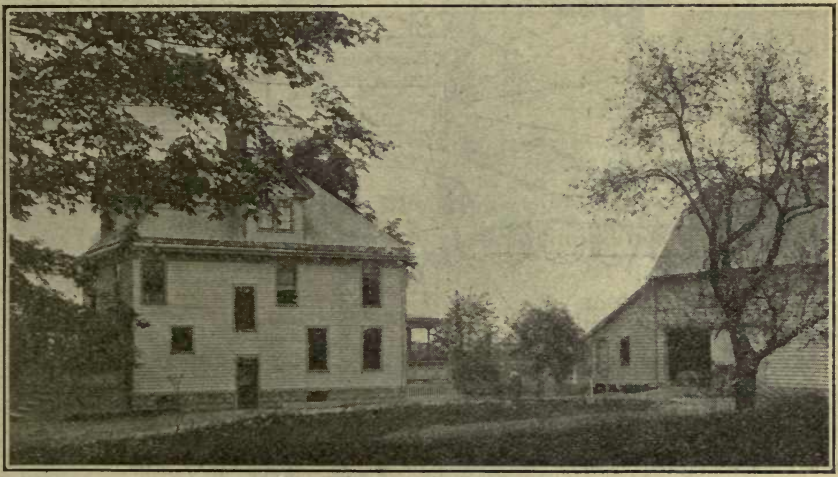

FIG. 5.—A city house in the country.

family is that of beautifying the farmstead, so that it may be more attractive to the occupants. This, in turn, will tend to make both young and old more contented. It will also add materially to the enjoyment of those who pass by and thus incidentally to the selling value of the farm.

Neglect of such improvement is usually due to one or more of the following causes: (1) Opinion that it will require too much time and work for upkeep, (2) a feeling that the improvement will be unsuited to farm conditions, (3) a belief that any adequate improvement will be too expensive, (4) indifference, and (5) a lack of understanding of what can be accomplished by expending a little effort in this direction.

DESIRABILITY OF MAKING PLANS FOR IMPROVEMENTS IN ADVANCE.

A farmstead consists of the farm buildings and the land immediately surrounding them that is necessary to their proper use and to the making of the home. Under this definition, not only are the buildings and the approaches from the highway a part of the farmstead, but also the cattle, hog, and chicken yards and the vegetable, fruit, and flower gardens. (Fig. 6.) Because of the intimate relationship between the farm home and the farm business all these things must be taken into account when planning to improve the

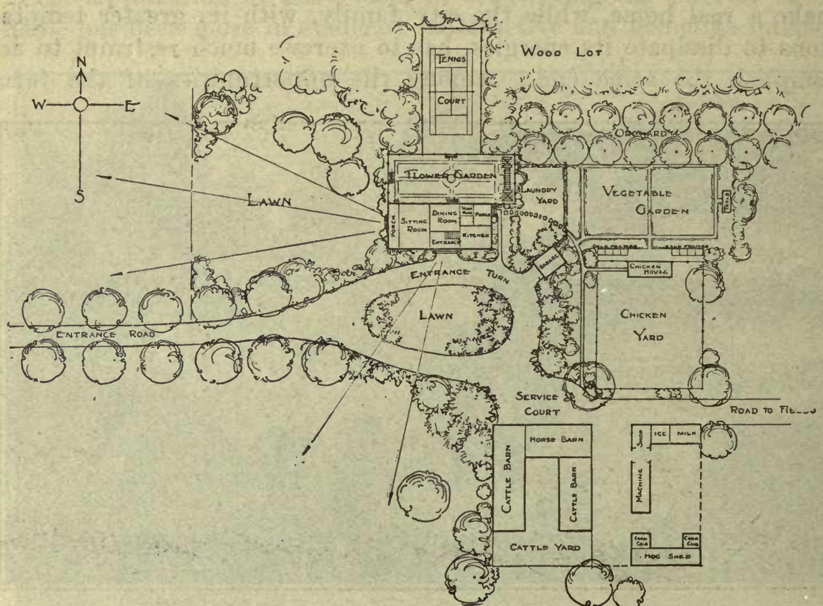

FIG. 6.—A plan for a farmstead where the buildings are back from a north-and-south road.

home surroundings. Not only the house lot but the whole farmstead must be considered.

Before any improvement can be made some idea must be formed as to what should be done. Are any changes in existing buildings, roads, or other permanent features desirable, and, if so, how can they be made, and, after all, will the change really be an improvement? (Figs. 7 and 8.) Such a consideration of the conditions is planning, whether the results are held in the mind of the one doing it or are put upon paper either in the form of written memoranda of the changes to be made or as a drawing showing what is to be done.

In order that the whole family may be interested and thoroughly understand what is being considered and have an opportunity intelligently to offer suggestions, it is desirable that some memoranda be put upon paper. The more complete this is and the more carefully it is worked out, the less is the likelihood of unexpected difficulties arising as the work progresses. It is appropriate to include features that may not be carried out for several years (fig. 9), so these improvements can be made when the time comes without interfering with other features of the plan.

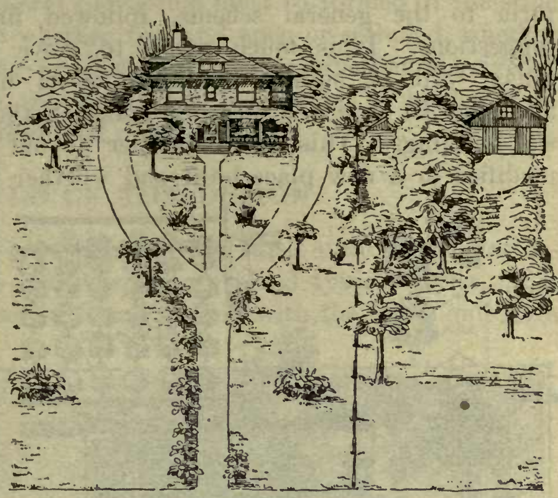

Fig. 7.—Undesirable arrangement of an approach to a farmstead. Compare with figure 8.

When an established place is to be improved is should be studied in the same way as a new place, forgetting all roads and structures, except, possibly, the largest and most expensive buildings. In making the first studies, even these should not be assumed to be incapable of being moved or altered. Then plans should be made which incorporate the buildings as they exist. If the last plans made are not as satisfactory as the original ones, alterations should be considered until a practical compromise is evolved, even though it require changes in permanent features, such as roads and buildings.

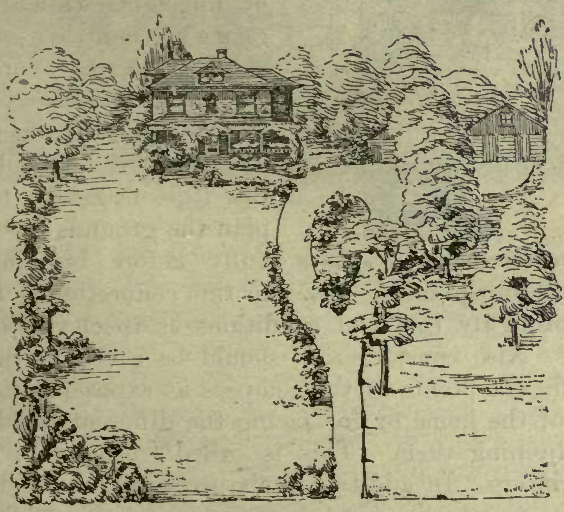

Fig. 8.—A revised design for an approach to the farmstead shown in figure 7.

In planning a new place the first thing to be considered is the approximate location of the principal buildings, with the space they should have about them and the relation of that space and of the buildings to one another. Then the necessary drives and walks, including the approaches to the buildings and all service features, should be located. After this, the detailed plans of the buildings should be worked out to conform to the general scheme, followed finally by the planting suggestions. It is much easier to move a building before the cellar wall is built than after it is up, and much annoyance can be saved by making plans of the grounds and then of the buildings. This holds whether an old place is to be slightly modified or a new place built and whether the work is to be done by the owner or by landscape designers and architects.

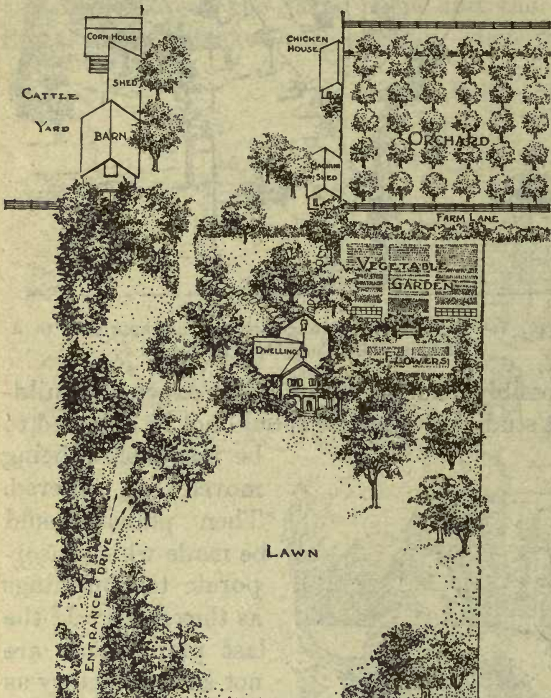

Fig. 9.—Plan of a farmstead located near the highway.

It frequently happens that houses and barns are put up without seriously considering their relation to one another or to the means of getting to and from them. Awkward situations often arise even in flat countries from such lack of foresight, while in rough countries almost impossible conditions frequently occur from such neglect. To prevent difficulties it is necessary to plan the grounds carefully before building and then make the building plans to suit. In this connection it is essential to study thoroughly the land conditions as to elevation, slopes, and drainage.[1] Also consideration should be given to the desirability of the different points of the compass as exposures for the important rooms of the home or for facing the different buildings or the yards adjoining them. This is called "orientation" by architects and engineers. In addition, it is necessary to decide whether the development is to be simple and inexpensive or elab-

[1] Topography is a general term applied to elevations, slopes, hollows, marshes, water courses, and other surface features of the land. A map showing such features is known as a topographical map.

orate and pretentious; whether the greatest possible economy of funds and lands is essential or whether a liberal expenditure is permissible. Further, a general conception must be formed of the style of place that is desired; whether free and open or secluded, whether austere and commanding or cosy and retiring, whether massive or airy, palatial or simple, somber or gay, pretentious or modest, forbidding or hospitable, dignified or riotous.

STYLE OF THE DESIGN.

So far no distinctive type of American farm architecture has developed, although some localities have evolved typical styles. Examples of these are found in New England with the house and barn

Fig. 10.—Typical New England farm buildings.

connected by a woodshed (fig. 10); in central New York with a story and three-fourths house and a moderate-sized barn; in southeastern Pennsylvania with its bank barn of stone, stable high with an "overshoot" on the south (fig. 11) and a moderate-sized dwelling; and in the South with large houses (fig. 12) and the other farm buildings subordinated. Because so much of our farming country is flat it would seem that the ultimate prevailing style should be low and spreading and that the prevailing lines should be horizontal, to make them harmonize more nearly with the landscape. Small communities with special conditions will be likely to develop their own styles.

An important thing is to have the buildings on any farm sufficiently similar in appearance to seem to belong together (fig. 13). The barns should all be of the same general style, and the houses should be livable and attractive, but not so different in their general lines as to seem out of place (figs. 14 and 21).

After these factors are determined the type of landscape treatment must be studied so as successfully to apply that which is best adapted to farmsteads. In general, only informal designs are applicable except in limited garden areas, but in order to understand informal design better it is desirable to have a clear idea of formal design. Formal design in landscape (see the flower gardens shown in figs. 4 and 36 and the plan illustrated in fig. 15) is composed of geometrical figures, usually symmetrical,[1] and always balanced.[2] It is freqently emphasized by architectural or sculptural additions. In general, the more straight lines are used the greater is the formality. The buildings need to be regularly and symmetrically placed

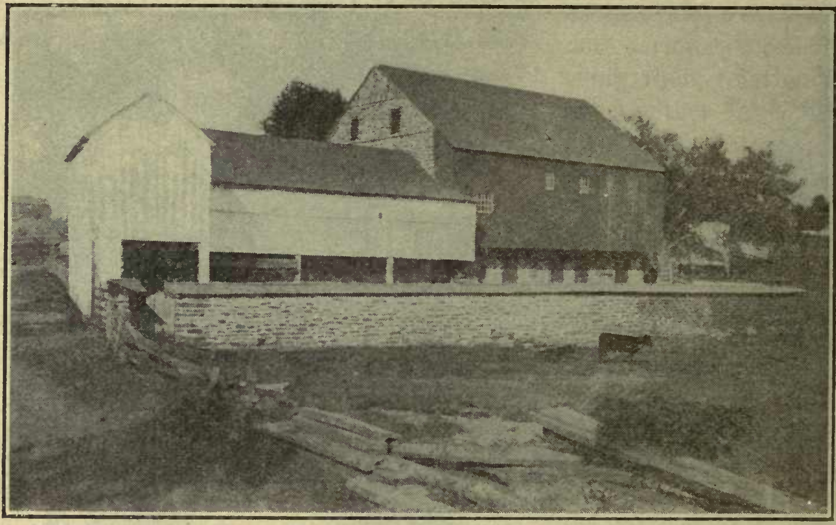

FIG. 11.—A typical barn of southeastern Pennsylvania.

and appropriately designed. The gound must be graded to suit the plan. All the details both of grounds and of buildings must be carefully worked out to conform with one another, and the upkeep must be of the best continually. Formal design is inelastic, not readily permitting additions, and is relatively expensive both in installation and maintenance.

[1] "Symmetrical" in landscape design means that each part on one side of a central axis is exactly duplicated on the other. Each half of the design reflects the other half. This does not mean that the two sides must be alike in their details, as the design may be symmetrical only in general outline.

[2] "Balance" in landscape design means that the features on each side of an axis are of equal interest, but not necessarily alike. A symmetrical design is balanced, but a balanced design need not be symmetrical. The axis must be in the center of the interest, not necessarily in the center of the design. A large area of lawn with little planting on one side of a walk may be balanced, for example, by a smaller area on the other if it contains more striking objects.

Informal design in landscapes (see figs. 6, 9, 16, and 28) is composed of irregular, unsymmetrical, unbalanced figures. In its purest form it consists entirely of irregular curved lines. When straight lines or regular curves do appear in informal landscape designs they are united with architectural features, such as buildings, boundaries,

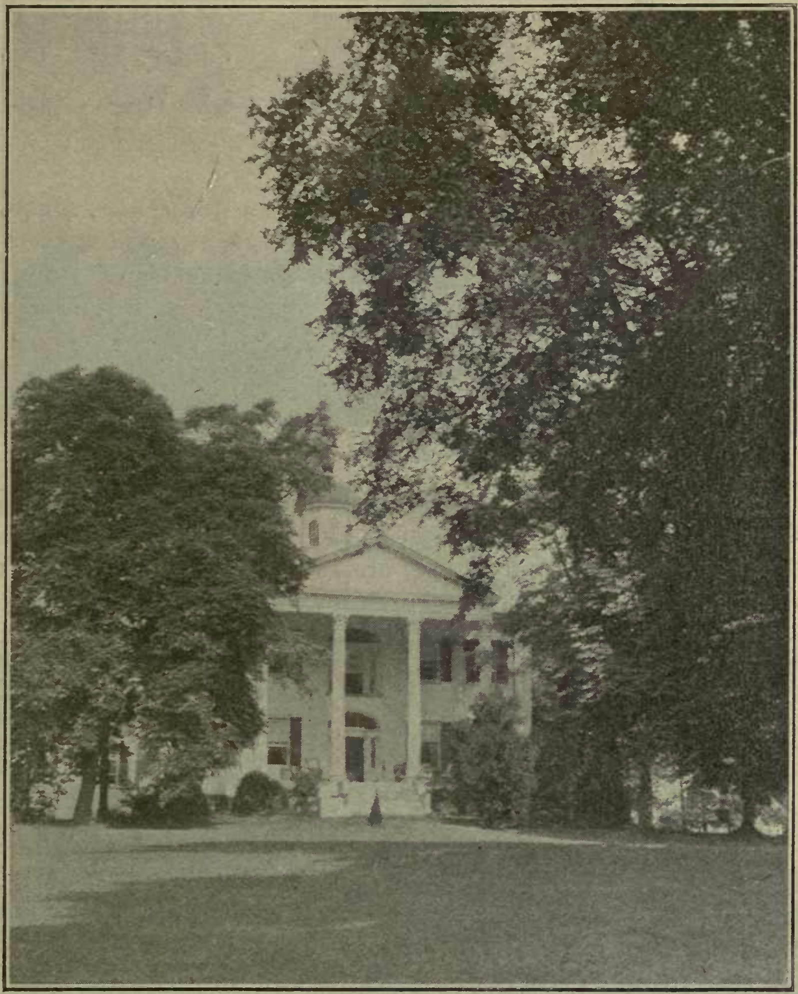

FIG. 12.—A typical mansion south of Mason and Dixon's line.

steps, tennis courts, and formal gardens. Informal design is economical in development, as it usually can be made to conform closely to existing conditions, thus reducing grading to a minimum. It can be maintained with little work.

Each plan is a study in itself and only by considering the conditions to be met can a successful one be made (fig. 15). The making of a good plan of the informal style is not difficult if an effort is made to meet the existing conditions without attempting to do things simply for show.

In applying the suggestions made in the following pages it will be found frequently that more than one applies to the particular case

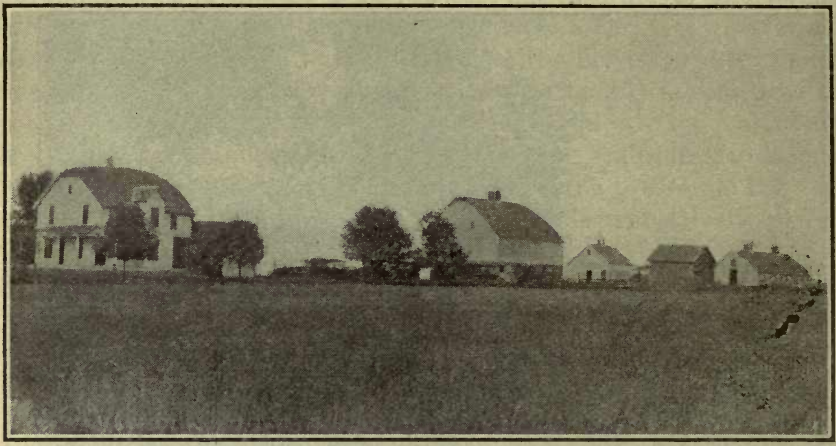

Fig. 13.—Buildings should appear to belong together.

but if that one is carried out the other can not be followed. The designer has to choose between such alternatives. The successful plan is one in which compromises are successfully made to give a livable, workable whole with an appearance of modest comfort.

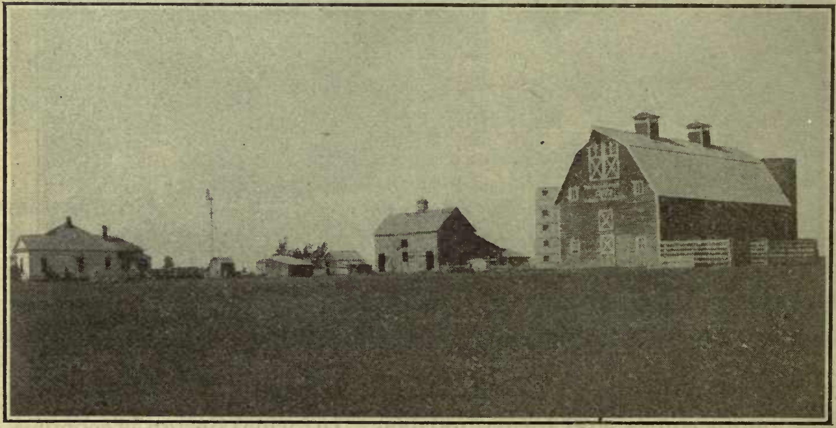

Fig. 14.—Farm buildings out of harmony.

Although the number of details requiring attention may seem confusing on the first reading, when the attempt is made to apply them they will be found to be comparatively simple. On most farms this work can well be planned and carried out by the farmer and his

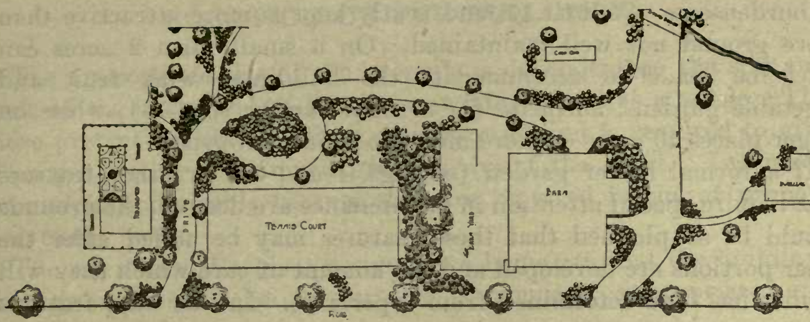

Fig. 15.—A plan for a farmstead when a good house, barn, and tenant house were already erected close to the public road.

family. It is necessary to decide, first, the working and living conditions that need to be met, and, second, the impression which it is desired that the home shall give. For the more expensive places and for smaller places where much grading is involved, the employment of a landscape designer is usually more satisfactory and economical. In most communities there are no well-trained men available to advise in such matters on terms within the reach of the small-home owner. In localities well organized for community work it may be possible to secure a landscape designer and an architect to help several in the community at one time. If the plan is good much can be accomplished in the way of improved appearance with only a little work required for installation and maintenance. If too much ground is included in the farmstead or the design is made too intricate, the care of it will

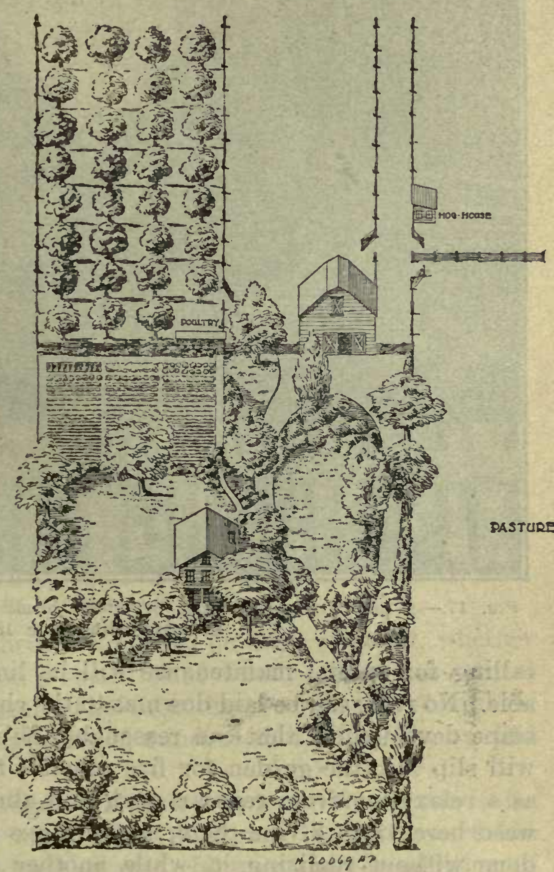

Fig. 16.—Plan of a 2-acre farmstead.

be burdensome. A little ground neatly kept is more attractive than more ground not well maintained. On a small farm 2 acres can often be made to accommodate the buildings, with fruit and vegetable gardens, adequate for a small family (fig. 16), while on larger places 10 acres or more may not be inappropriate.

If a formal flower garden (see figs. 4 and 36) or other features that require special attention in maintenance are desired, the grounds should be so planned that these features may be added after the other portions are developed and the amount of care which they will require has been determined from experience. In this way, features

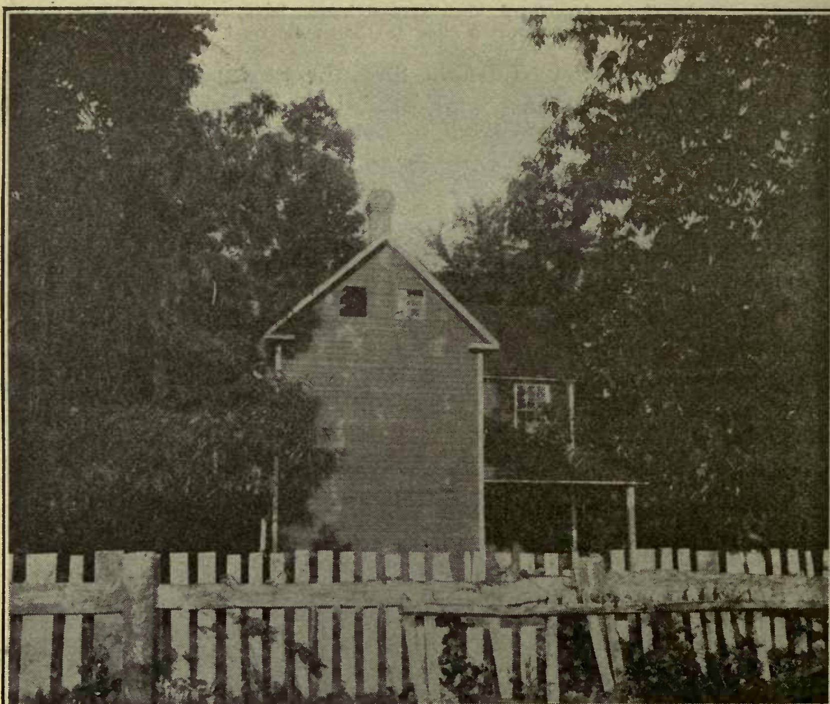

FIG. 17.—A familiar type of farm or tenant house in many parts of the country. Compare with figure 18.

calling for special maintenance will be limited to the labor available. No rules can be laid down as to the character or extent of landscape development that can reasonably be maintained. One person will slip into the garden for five minutes two or three times a day as a relaxation from regular work and almost unconsciously pull a weed here, train a vine there, and so have a large part of the work done without realizing it, while another can not accomplish this without a special trip for the purpose. The personal tastes of the members of the family will determine very largely the extent and character of the development.

LOCATION OF THE BUILDINGS.

The appropriate size of the grounds is dependent on the size and style of the house and of the farm and farmstead as a whole. The more pretentious the buildings, the more ground is required to give a proper setting. Cramped grounds dwarf the effect. Too much ground is undesirable because the care required is out of proportion to the needs.

The essentials of a good design for a home are that the buildings and grounds shall be comfortable, convenient, appropriate, and

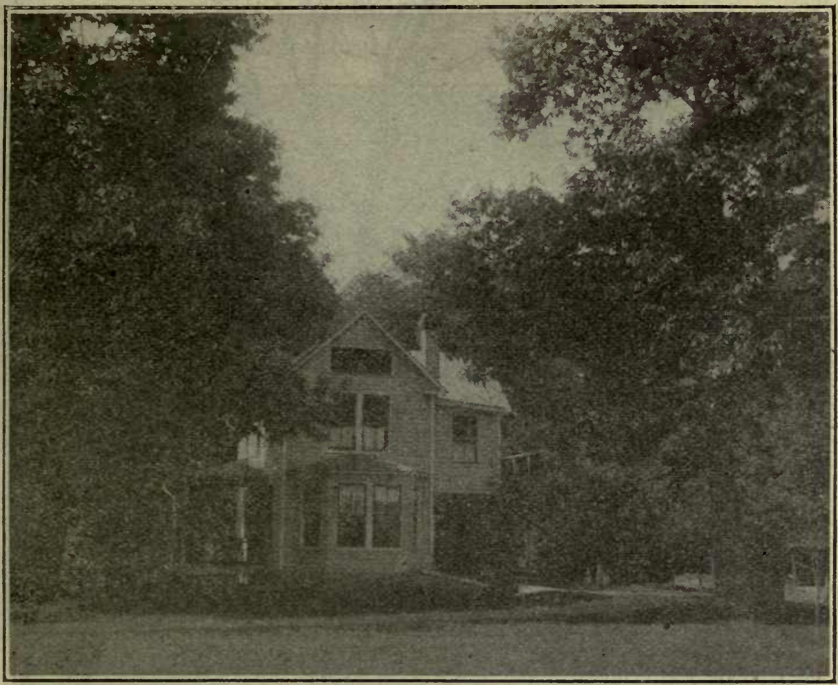

FIG. 18.—A transformation in the appearance of the house shown in figure 17, made by attention to details.

attractive. This holds whether the place be large or small, whether there is one small house on a small lot or whether there are several large buildings on a farm. The first three conditions should be solved with the fourth constantly in mind, so that all will be worked out together.

Sometimes a slight change will work wonders. Every one is familiar with the type of house shown in figure 17, but few realize how the changing of the location of a chimney and the addition of windows and porch will improve its appearance, as shown in figure 18. Of course, the removal of the fence adds to the attractiveness of the place, but by covering the lower porticns of both pictures it will be seen that the fence is only a minor factor. The exposure is one of the most important considerations for securing the comfort of the family. In cold countries protection from the winter winds

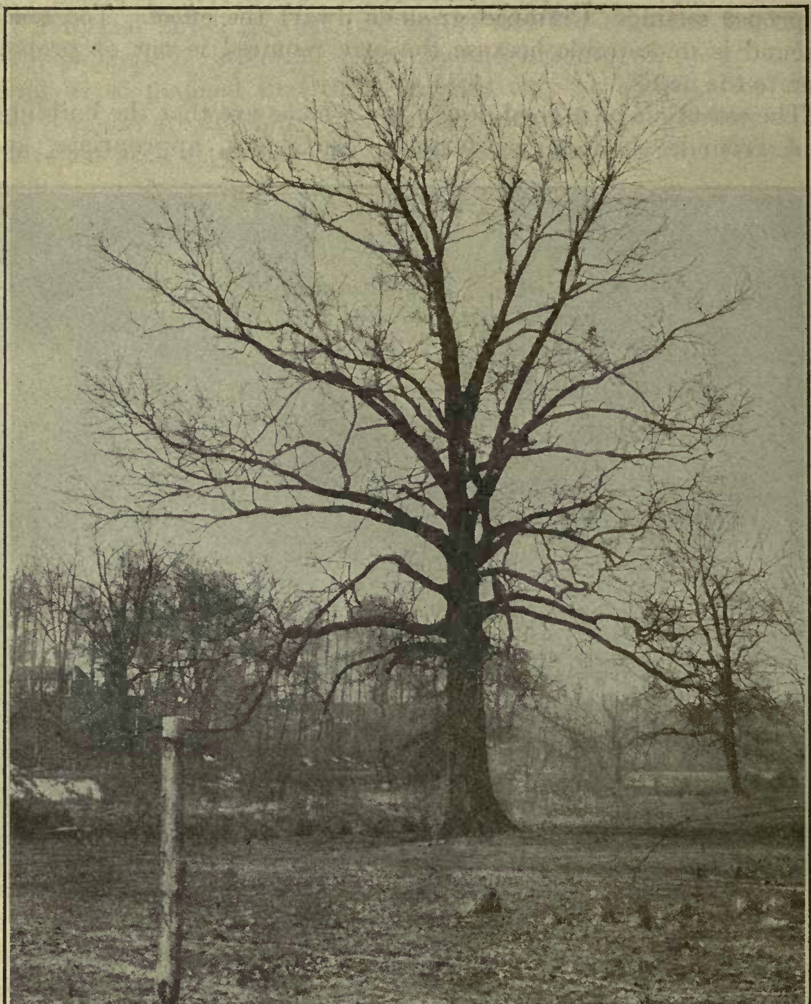

FIG. 19.—A view from a living-room window.

is desirable and the location of the most used rooms should be on the warmest side of the house, while in warm countries the house and living rooms need to be so located as to get the benefit of the prevailing winds during the hottest months.

The elevation should be such as to make possible thorough drainage, even though it may be desirable to keep off the highest ground.

Under no circumstances should the house get the drainage from other buildings.

If at all possible, the house should be so located near good trees that their shade may be used and enjoyed by the family every day during the summer. It takes so long to grow good trees that existing trees should be cherished and utilized to the fullest extent.

The outlook, too, should be well considered and the rooms used most should be given the benefit of the best views; those from the kitchen as well as from the living room should be attractive. The near view should be over an unbroken lawn, and there should be some object of interest beyond. If there are no such objects in the general landscape, such as a mountain, a water view, a woodland, a meadow,

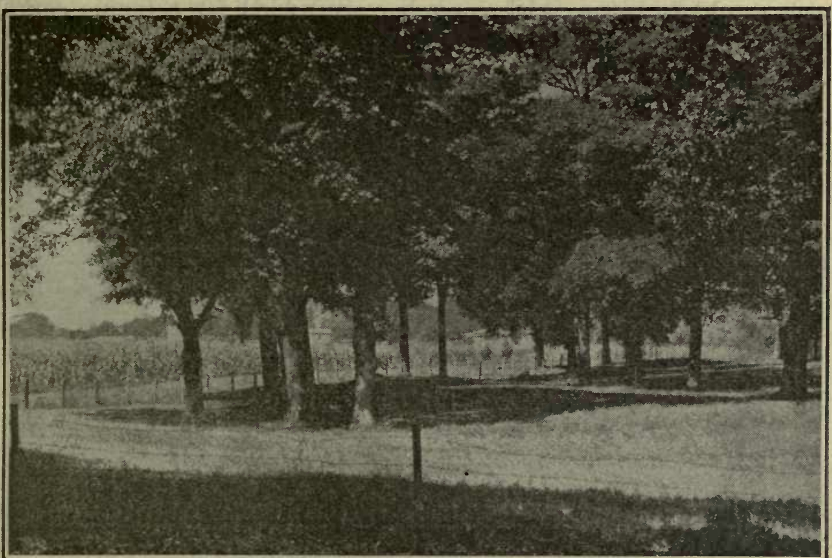

FIG. 20.—A pasture as an extension of a lawn.

or an extended farm view, a handsome tree (fig. 19) or other bit of near-by landscape may be available. Lacking these, possibly some feature may be created on the place, such as an attractive group of shrubs, well placed and arranged so as to have something of interest each month. Good views should be sought or created and utilized to the greatest advantage.

In a hilly or mountainous country a site should be selected that will provide a little level land immediately adjoining the house. This is necessary both for appearance and for comfort in living. Where such a setting is not provided the house is likely to give the impression of being about to slide from its location, while with a little level ground close by it may give the appearance of fitting closely into the site. In the case of a side hill or bank house it may be necessary to build with one side facing on a higher level than the other. If the level areas are of reasonable extent, although at different heights and separated from each other, the desired impression may still be given. The many discomforts of living with a side hill at the threshold are a vivid reality only to those who have experienced them.

The area that should be set aside for the house lot is dependent on so many factors that it is hard to give rules. The larger and more pretentious the house the more land should appear to be with it. The least there should be is the greatest amount of space that the family can use and enjoy. The minimum would seem to be five times as much ground as is covered by the house, although twenty times as much would be better, with enough room added for a tennis court,

FIG. 21.—A farmstead having too many unrelated buildings.

croquet ground, or other playground, and a liberal flower garden. Though it may be necessary to have a lawn which is small, it is frequently possible to increase the apparent size by making adjacent areas appear to belong with it (fig. 20). If the apparent size can not be increased, as suggested under lawns, it should be at least possible to prevent the dwarfing of the appearance by growing only low crops in the near-by fields, keeping tall crops and orchards at a little distance. Where this is impracticable the area of the home lot should be doubled or trebled.

The barns as well as the house should be well located, and not only must they be properly arranged to facilitate the farm work and be accessible to the road, but they must be reasonably convenient to the house without being too close, prominent, or obtrusive. They should be so situated with respect to the house that the prevailing winds, especially during those seasons when the doors and windows are likely to be open, do not blow from the barns toward the house. On the other hand, in cold climates the barn as well as the house needs protection from severe winter winds.

Further, the buildings must be arranged for convenience. The interior of the house and its connection with the outside features, whether with the barns or the public road, should be adapted to the everyday life of the family. All too common examples of inappropriate farm architecture are front doors that are never used except for funerals and parlors that are so seldom used that when they are used they cast a reserve over the whole family. Drives and walks to such front doors are a meaningless formality and should be eliminated. In a house of such design the neighbors usually go directly to the kitchen, because they know that is the entrance the family uses, and the life of the family is so far from the front door it is impossible to get any response even if the attempt is made. A more pleasing and satisfactory arrangement is to have the entrance open directly on the part of the house the family uses, as shown in figures 6 and 9.

The entrance should be so located as to be easy and natural for both the family and visitors to use. The approaches to it should be so direct that there is no feeling of being taken out of the way in following the roads or walks provided. In such an arrangement the entrance and approaches are naturally used in accordance with their design.

The barns should be at a little distance from the house, but close enough to facilitate the work to be done, and of such a character architecturally that they look as though they belonged together. The buildings should be as few in number as is practicable, or at least should have the appearance of being a unified group from the principal viewpoints. Such results can be brought about by careful grouping, sometimes even building them around a courtyard, or if necessary connecting some of them by sheds or walls. The objection to close grouping is the danger from fire, but facility in doing the work may be an offset to this. A number of small unrelated buildings gives a " cluttered up " appearance, as shown in figure 21.

WALKS AND DRIVES.

The entrance to the farmstead from the public road is one of the most important details of the plan and one of the most difficult to treat successfully without underemphasizing it or overdoing it. It should be so located as to facilitate direct and easy access to both house and barn and make the approach to either seem natural and easy, while at the same time appearing to lead primarily to the house. On the other hand, it should not be directly opposite the front door of the house, so that on entering one appears to be going straight into the house, except possibly in extremely formal de-

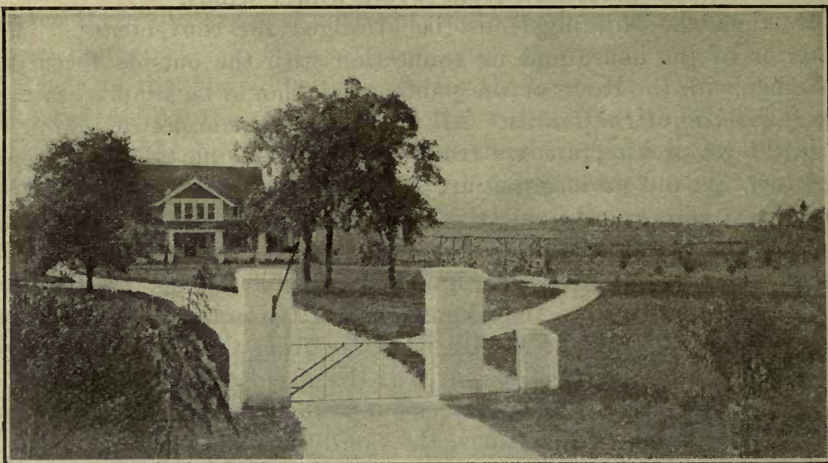

FIG. 22.—An entrance that gives a bad impression. Compare with figure 23.

velopments. In informal developments an entrance to the farmstead on the axis of the front door is not pleasing, even though the

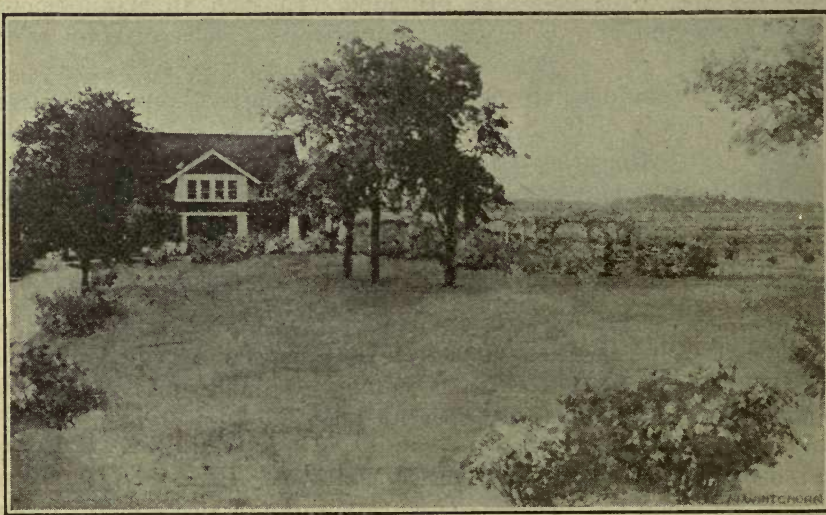

FIG. 23.—The farmstead shown in figure 22 improved by placing the entrance to one side.

approach road swings well to one side after leaving the entrance. (Figs. 22 and 23.)

The entrance should largely reflect and suggest the character of the farmstead. If the farmstead is formal, the entrance should be formal, but if the farmstead is informal, the entrance should be simple. The less formality there is in the farmstead the less there should be at the entrance. On the other hand, some special treatment is necessary to attract attention to it and set it apart from the rest of the boundary and to invite entrance, at least to the extent of inciting the wish to enter in those passing.

The character of this special treatment must so nearly correspond with the rest of the treatment of the farmstead that it can be united with it without an abrupt change of style at any point. The transition from a heavy stone or brick post to a barbed-wire fence is difficult unless the size of the farmstead is such that there is sufficient

FIG. 24.—A well-designed entrance. The appearance of the stone wall has been improved by recessing the cement joints.

distance to make the transition gradually. If the post is flanked by a wall of the same material that ultimately becomes the same height as the fence and the fence and wall are covered with vines for a considerable distance on each side of the joining, a successful transition can be accomplished. Such a stone wall, however, is inappropriate unless built of native stone in evidence in fences or buildings in the neighborhood or else is like the stone or brick clearly evident in the foundation or other portion of the buildings.

The design of the wall also has an important bearing on its appropriateness. The wall of native stone in figure 24 is appropriate and attractive. Figure 25 also shows a good entrance for its location, but one which would be most inappropriate were it not for the heavy background of trees. The wall is good and is well covered with

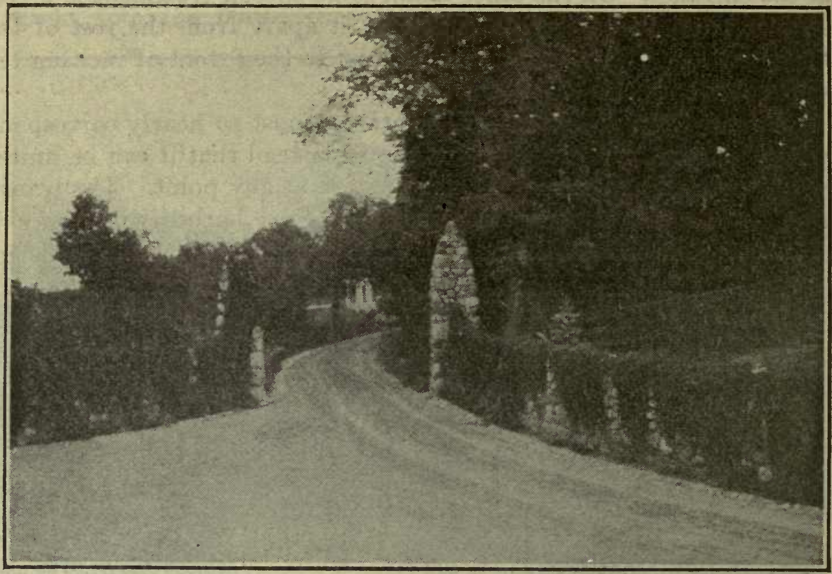

FIG. 25.—A good gateway and wall for the location. Were it not for the mass of foliage behind, the posts would be too tall and too heavy.

FIG. 26.—A wall suited only to a formal landscape.

vines. The posts would be too heavy as well as too tall in most situations. The wall in figure 26 is so formal in design that if used at all it should be only with a formal landscape, and then only when the buildings are of a similar checkered design.

Plants can be much more easily arranged to emphasize an entrance without overdoing it than can architectural features. Entrance plantings may either be formal, such as hedges or regularly placed specimens or clums, or they may be altogether informal and irregular, as shown in figure 27.

As with all other details of the farmstead, development at the entrance, whether primarily of plants or of other material, must be appropriate in size, shape, and kind. Especially with plants there is a wide latitude of possibilities that may be appropriate, but the limits must not be exceeded if a fitting result is to be obtained.

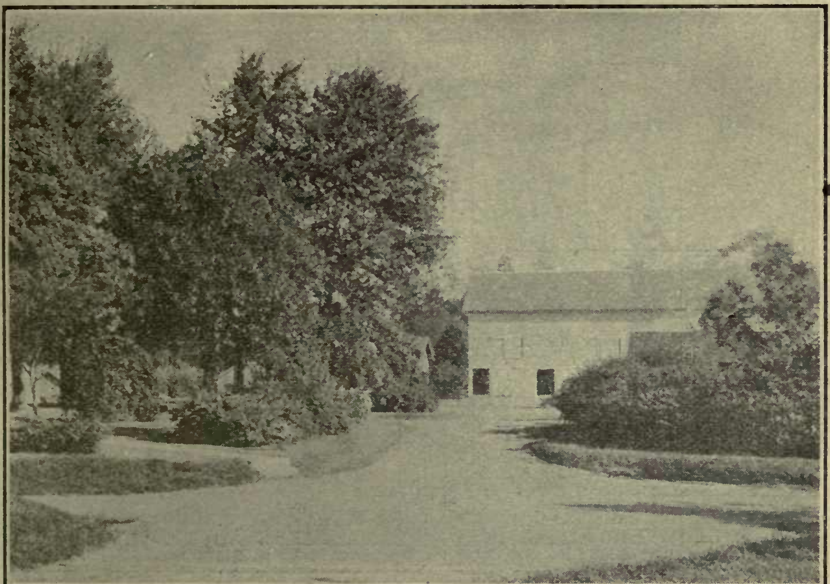

Fig. 27.—Informal plantings at the entrance to a farmstead.

The approach to the farmstead should be direct, but as a rule not straight toward any of the buildings. Where the buildings are near the highway a good plan is to have a single road enter the grounds, then to divide, one branch going directly to the barn and the other past the side of the house, passing near the main-entrance door, thence near the kitchen entrance, rejoining the road to the barn in such a way that the traffic may conveniently pass to the barn or return to the highway. (See figs. 6, 16, and 28.) This arrangement of a double road is to permit traffic to reach the barn without passing close to the house, while not greatly increasing the extent of road surface. The approaches should be so curved as to permit plantings to hide partially the barns and service yards and thus screen them so that they will not be too conspicuous to those approaching. In hilly countries the topography or lay of the land will largely determine what may be done in the matter of approaches, and it correspondingly gives opportunities for variety of treatment.

In flat countries the problem of providing a convenient approach is not so difficult, but, on the other hand, it requires considerable thought and care to have it convenient without being commonplace and uninteresting.

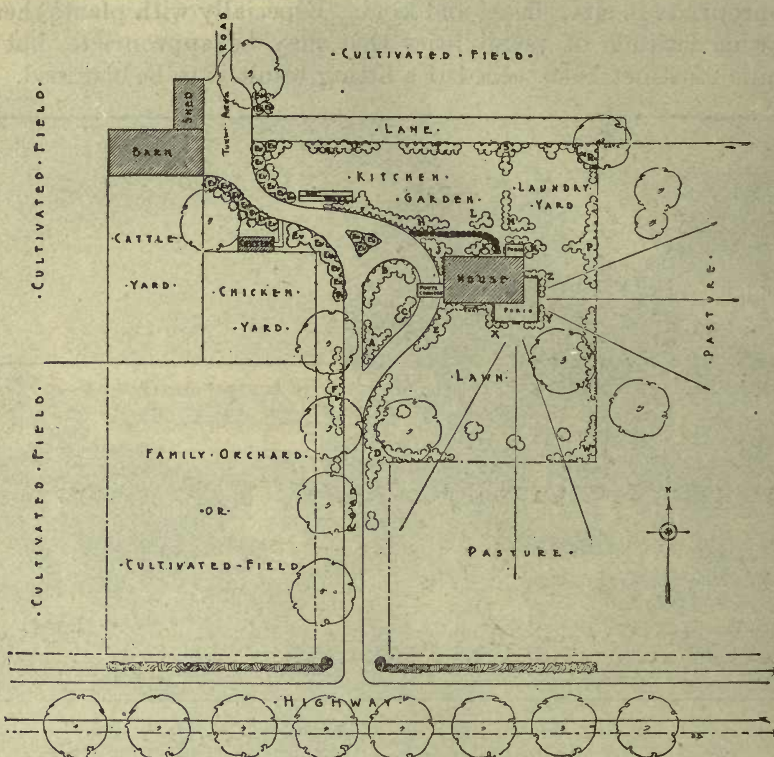

FIG. 28.—A good approach to a farmstead.

Where the buildings are located some distance back from the highway an approach from the public road to the group of buildings becomes necessary. In hilly countries this approach will often need to be curved or crooked in order to avoid objectionable grades. As far as possible the road surface should be kept hidden from the home, but on approaching, the visitor should from time to time get glimpses of the house and should feel that he is going toward it, although not straight at it. In a flat country, especially where the farms are all laid out in rectangles, the approach road from the highway had better be straight till it reaches the farmstead (fig. 29), when the same general scheme may be adopted as though the farmstead were located directly on the highway. Such an approach road will be likely to run parallel to the lines of the house and barns, but it should not run directly toward either. A public building may be appropriate as the terminus of a vista made by a straight approach road, but a farmhouse or barn seldom is. A long straight approach road is made more effective by a row of trees on each side, forming a vista under their tops. There should be some attractive object to which the eye is drawn at the end of the vista, or at the "focal point," as it is called. This object may be an attractive landscape, a beautiful tree, or a clump of shrubbery. It is seldom desirable to have

Fig. 29.—A good entrance to buildings located well back from the highway.

an entrance door at the focal point of a combined business and home drive, such as the approach to a farmstead. Where a door is used as the focal point of a formal drive it should be merely an entrance door, not the door that leads to the lawns and pleasure grounds of the family, as the latter should have more privacy than could be given a door fully exposed to view from the main approach. On the other hand, ugly or uninteresting objects should not be the terminus of such a vista. (Fig. 30.) Trees or a clump of shrubbery, especially if composed mostly of evergreens, can help such a situation greatly. The other walks and roads about the farmstead should be as few as possible. All real needs should be met, but no provision should be made for fancied or possible ones. If in doubt leave out a walk until experience shows the need of it. The place where it is supposed it might be needed can be put in turf until its need is demonstrated.

FIG. 30.—An inappropriate approach to a farmhouse. The opening to the woodshed could easily be screened by a careful planting of evergreens.

FIG. 31.—A good approach for buildings near the highway.

All roads and walks should be so located as to give the feeling of leading to their destination without unnecessary turns. This does not mean that they must be straight. They may be slightly curved and yet give the impression of leading to the desired end. In informal designs, where the distance is not too short, a curved walk or drive (fig. 31) gives a more pleasing effect than a straight one. The amount of curve need not be great, often a deviation of the width of a walk or drive (fig. 32) will answer, while 1½ times its width will be ample. On the other hand, curves should not be too abrupt, and there should appear to be a reason for each. Appropriate plantings can often be made to supply this reason if no other can be provided, and they are always useful in supplementing other reasons. In a rolling or hilly country the slope of the land can usually be made to give an excuse for the curves.

FIG. 32.—A satisfying result with a slightly curved roadway, a deviation of not more than its own width.

Paths and roads should not only be as few as possible, but should be kept out of sight as far as is feasible. Where practicable to conceal them, at least partially, by construction behind knolls or through depressions, it should be done if it does not interfere too seriously with their directness and if good drainage can be provided. Often artificial knolls and depressions are constructed to hide them, but this is seldom warranted unless the farmstead is large and the fund for development is liberal. On the other hand, a study of conditions and a little work may often accomplish wonders. Finally, plantings of trees or shrubbery may be used (fig. 33) after everything practicable has been done in other ways. Paths should not be installed where established roads can be utilized, even though it may take extra care and expense to keep the road surface in condition for the dual purpose of a walk and drive. If it should not be practicable to keep the road in good condition for foot traffic, of course a separate footway would need to be developed, but it should be omitted unless really necessary. Both from the standpoint of appearance and of expense of upkeep the fewest possible drives and walks should be provided. A little-used walk or drive is usually as troublesome and as expensive to keep up as a much-used one, as it will grow full of weeds and will wash whether used or not.

The surfacing will depend on local conditions. As a rule, farm roads will be made of the natural soil and should be well crowned and provided with good gutters with liberal outlets. In most parts

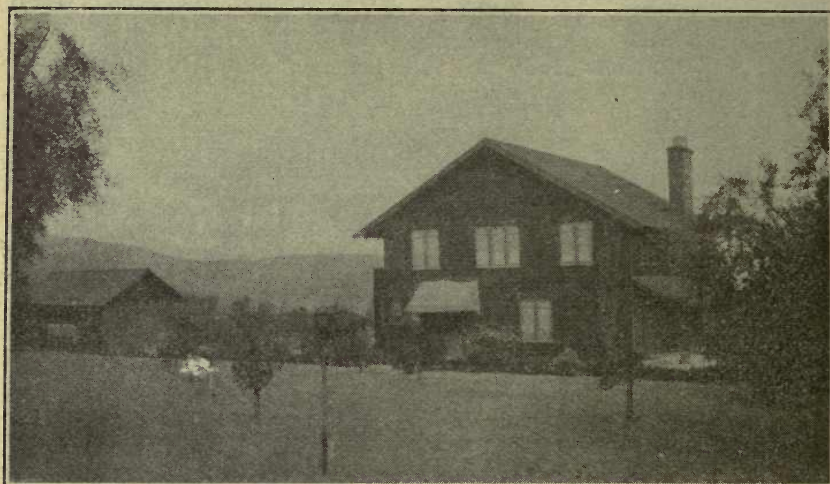

FIG. 33.—A well-hidden approach and service road. See figure 32 for another view of the same road.

of the United States little-used roads and many paths, even though much used, can be covered with turf and mowed, like the lawn. If the road is used sufficiently to cause ruts, soil can be brought to fill them. Where a more resistant surface is needed for a short time each season, stones 2 inches in size or larger may be mixed with good soil and the road formed of that material. Grass will grow in the soil and the stones will not permit a cutting up of the roadbed or the permanent destruction of the grass. The grass tops may be worn off by the traffic, but the roots will push out again after the wear ceases. Turf gutters (fig. 34) may be found satisfactory for road and walk drainage in all sections where there is sufficient moisture to maintain turf growth. To be successful, no ridge or shoulder should be permitted between the turf and the road. Some material always collects in the gutter, gradually raising it, so that every few years it is desirable to lift the sod, remove some of the dirt under it, and relay it. Although this may seem like a good deal of a job, it will probably have to be done so infrequently as to prove one of the most economical ways of maintaining a gutter. Where an artificial road surface is needed, it should be as inconspicuous in color as possible. Cinders are one of the most desirable private-road surfacings, both on account of the color and because of good road-making qualities. Oyster shells, crushed limestone, concrete, and light-colored brick each have an objectionable color, contrasting too strongly with the normal green of country surroundings. Limestone combined with some of the dark-colored asphaltic oils or concrete colored by lampblack is pleasing in appearance.

Fig. 34.—A turf gutter.

Turf makes a good surfacing for footways that are only in use under favorable weather conditions, but those that are used in wet weather, especially if much used when frost is coming out of the ground, need some other material. Where available, nothing is more attractive than flat stones placed in the turf with the grass growing between, as shown in figure 35, but they need to be set low enough to permit the lawn mower to pass over them. If a cement walk is necessary, a dark color should be given it by the free use of lampblack, while crushed-stone walks can be held together and more suitably colored by using some asphalt or coal-tar preparation.

SERVICE FEATURES.

Provision must be made for features that facilitate the work of the farm or increase the comfort of living. These include such things as work yards, storage yards, and cattle yards about the barns, an ice house, a place for the storage of fuel, and a laundry yard near the house. Fruit, vegetable, and flower gardens must also be provided. Such features are all necessary, but should be so arranged as to serve the needs without being unduly conspicuous. One feature frequently overlooked is the provision for the delivery of the fuel supply near the place where it is to be used from roads arranged for other purposes. Failure to provide this is a continual cause of vexation. An ice house should be convenient in order to supply the daily needs of the family and yet not too conspicuous or too inaccessible for filling.

Wherever possible, buildings for several purposes should be united or be so located as to appear as one rather than multiply the number

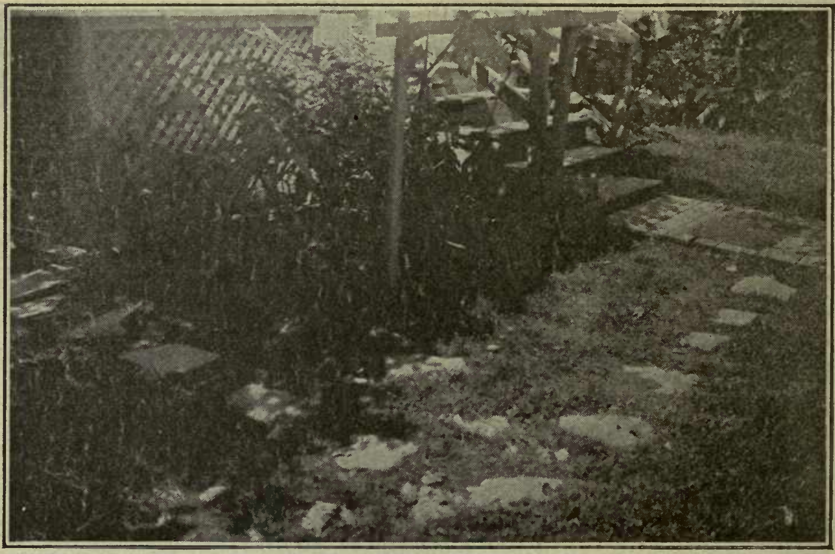

FIG. 35.—A stepping-stone walk.

of buildings, as a large number of small apparently unrelated buildings detracts greatly from the appearance.

The fruit and vegetable gardens and the garden for growing cut flowers for indoor decorations, as well as the ornamental flower garden, are part of the farmstead and should be used in its setting. They will be pleasing in appearance if properly placed, well laid out, well cultivated, and kept neat.

An orchard can add wonderfully to the setting of the farm buildings. A mature apple orchard kept in turf makes a delightful extension for a lawn. A well-arranged and well cared for fruit or vegetable garden is always attractive and may often take the place of a flower graden as a decorative feature and source of interest on the farmstead.

The placing of such gardens for the greatest effect may prevent cultivating them by horse power. This usually should be avoided, because it increases the labor in upkeep. If it is impossible to adapt the gardens to the location so that they can be efficiently cultivated, it is best to move them to a place where it can be done. Two essentials of an attractive farmstead are neatness and the evidence of cultural success. The accomplishment of these should be made as easy as practicable without unduly sacrificing the decorative possibilities. It should be kept in mind that the more ornamental the garden is designed to be, the greater the care required in its culture and maintenance. The careful placing and arranging of fruit and vegetable gardens, however, should not be made an excuse for

FIG. 36.—A formal flower garden with informal plantings.

omitting a flower garden, even though it has to be a small one. Occasionally it may be combined with the vegetable or the fruit garden.

An ornamental garden, whether devoted to flowers (see fig. 4), vegetables, or fruits, is in the nature of a transition from the formalities of the house to the informalities of the lawns. Its purpose and use should be largely that of an outdoor room. For this reason it should be near the house and somewhat secluded, having the privacy of a living room. In locating such a garden it should be kept in mind that views of the farmstead from the principal points should be largely open and free from special features that would distract the attention from the house. On this account, ornamental gardens should seldom be placed between the highway and the house, as the principal views are usually obtained from points on the public road. If they are so placed they should be made as inconspicuous as possible either by screen plantings or in some other manner.

An ornamental garden may be either formal (fig. 36) or informal, but in either case it should be regarded as part of the house and its activities, not as its principal setting. It comes closer into the family life if it is on the side of the house away from the public entrance and is near to the living porch, so that it is easily entered from the porch. It should be included whenever the family tastes and circumstances permit the expenditure of the extra labor involved.

Such a garden may be simple, involving little work, or it may be elaborate. It should be the most definite expression of the family

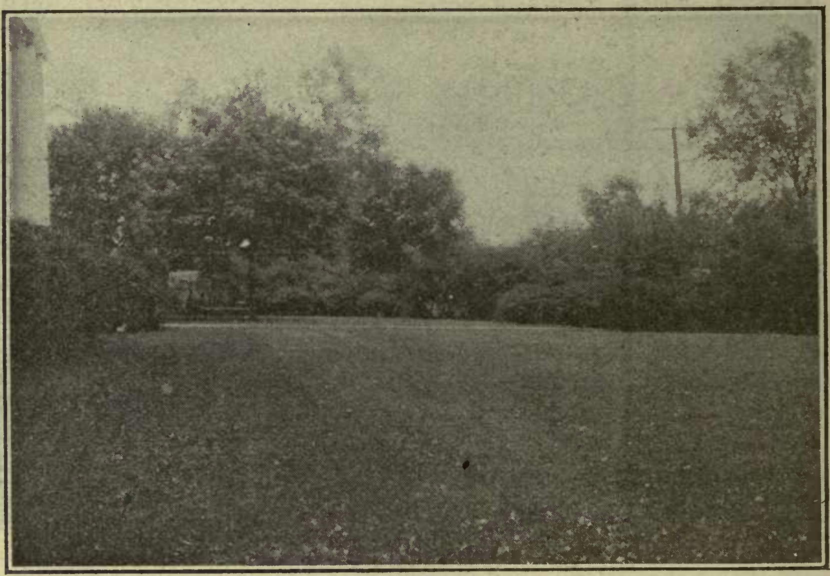

Fig. 37.—A lawn with irregular outlines.

tastes. A place for such a garden should be provided on the plan, but it may be left in lawn until the time comes for its development.

Probably the greatest enjoyment of such a garden comes in its gradual making. The first step can be the planting of shrubbery borders to inclose it, followed the next year by the cutting of a few beds near the borders or at carefully selected points in the turf of the garden floor. By such steps it can progress until an intricate garden is completed, with its numerous beds and turf or gravel walks, or the garden may be left with a turf panel and narrow beds partially or entirely inclosed by shrubbery borders. Walks, arbors, seats, a summer house, or a pool may be incorporated if fancy dictates. Here personal taste may find free expression with less restraint from surrounding conditions than in any other part of the grounds.

Flowers about the house are to beautify the grounds; therefore to depend on such flowers for cutting is to defeat the purpose for which they are intended. Although flowers may at times be cut from general plantings or from an ornamental flower garden without injury or detriment, yet such plantings should not be regarded as the legitimate source of cut flowers, nor should cutting be permitted to such an extent as to mar the appearance of the plantings as a whole. Most of the flowers for cutting for indoor decoration should be

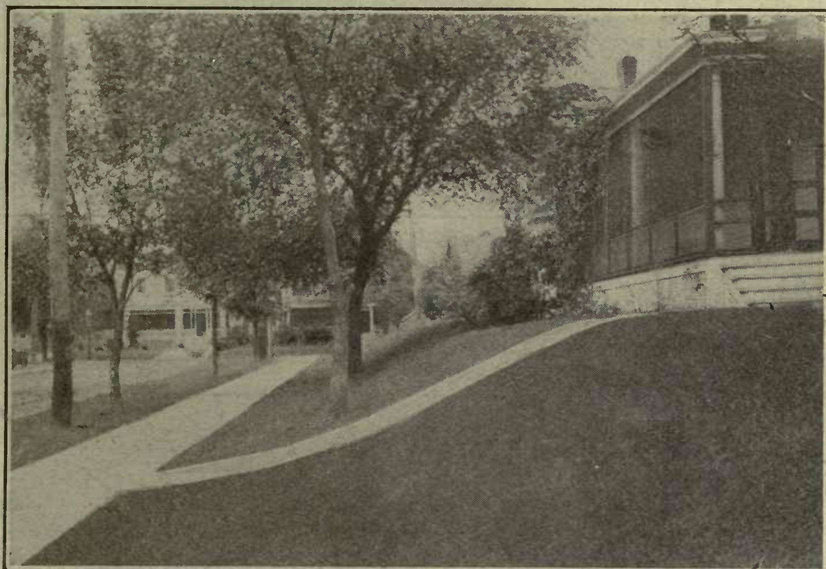

Fig. 38.—A sharp ogee. There should be no line between the convex curve at the top and the concave one at the bottom; they should merge one into the other.

grown especially for that purpose, either in rows in the vegetable garden, where they can be cultivated by horse tools, or in their own garden, which should be arranged for economical cultivation.

LAWNS.

Lawns are most important for beautifying the farmstead. They are the background or foundation against which all the details are viewed. They should be in as large and unbroken stretches as possible, as this produces a pleasing effect, tending to give an impression of great extent and also making them easier to maintain. The borders should be irregular, as shown in figure 37, for an irregular outline increases the apparent size of the grounds by not revealing at one glance their actual limits. When bays on the lawn are formed by appropriate plantings it adds interest, as the depth of all the bays are not visible from any one point and, at once, curiosity is aroused as to what may be in the hidden places; thus the grounds are made more interesting and give an impression of greater size.

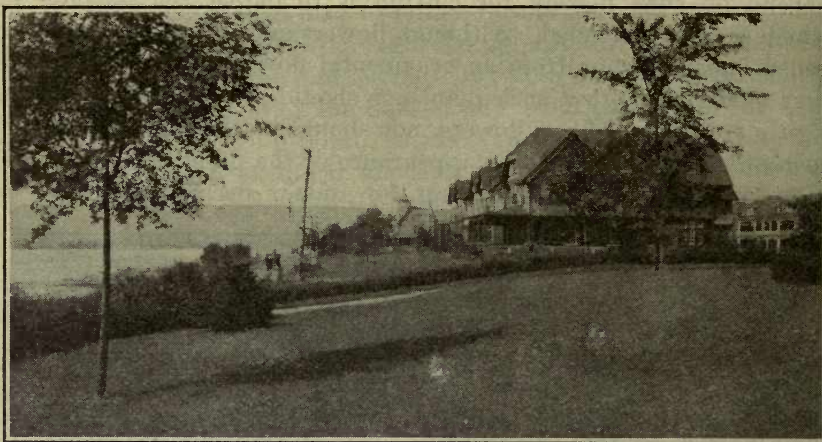

FIG. 39.—A long ogee.

The surface of the lawn should be smooth enough to permit the easy running of the lawn mower, but many of the natural undulations should be kept, and if the surface is inclined to be flat some effort

FIG. 40.—A bank held by rocks.

might be expended to increase them slightly. Steep banks are objectionable, as they are more difficult to maintain than moderate slopes. Wherever it is necessary to have rapid changes in grade, an effort should be made to accomplish it in the most natural manner practicable. If at all possible this should be by using a double curve, known to carpenters and landscape designers as an "ogee," which consists of a convex surface for the upper part of the slope and a concave surface for the lower part. Such curves may be either short and sharp, as shown in figure 38, or long and flat, as in figure 39. Where banks similar to those on railroad cuts or fills are necessary, they should be held in place by embedding rocks in the surface (fig. 40) when stone is available and planting among the stones or by setting out shrubs or vigorous vines (fig. 41), especially if the rock treatment is not practicable.

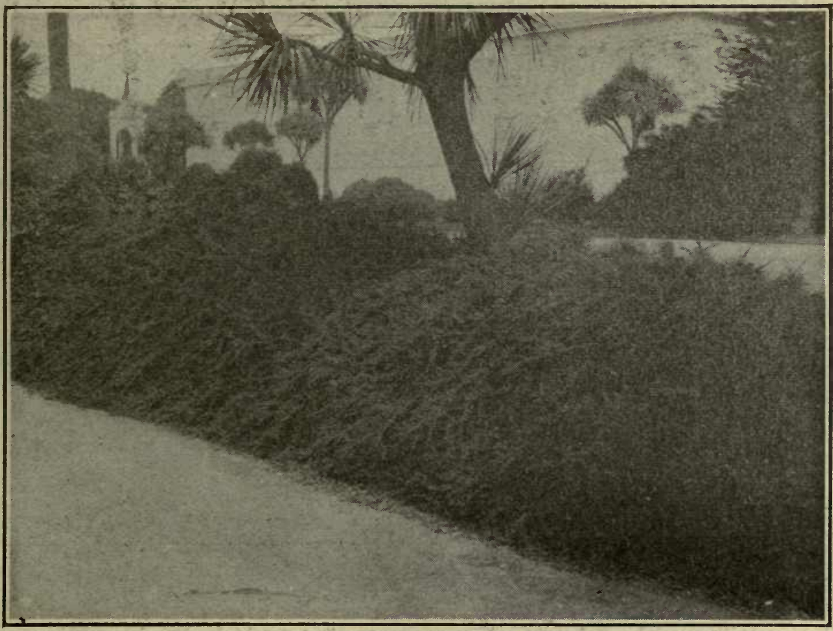

Fig. 41.—A bank held by vines.

Plane surfaces, either flat like a table or on a slope like a roof, are not desirable except in formal gardening.

The kind of lawn cover is important. The best for the region should be used, even if it requires a little more care to establish it. In most parts of the United States grasses can be utilized for lawns. In a few places other ground covers must be used unless great care can be given the lawn. Wherever it is at all practicable to grow it, grass is the most pleasing cover.

Lawns should be of sufficient size to give an ample setting, especially for the house. If well placed, 2,000 or 3,000 square feet may answer all purposes, although much more space is better. The apparent size of a lawn may often be materially increased by having a pasture adjoining it and separated by the most inconspicuous fence possible located in the least obtrusive position. (Fig. 20.) By care in scattering manure from time to time in order to prevent the grass from growing in clumps and by cutting weeds or grasses that tend to grow in bunches, such a pasture may be made a very attractive extension of the lawn, especially if it is provided with a few clumps of fine trees.

If the surface of the lawn is made reasonably smooth and it has been graded so that there are no steep banks, keeping the grass cut should be a comparatively easy matter. The finest turf is obtained

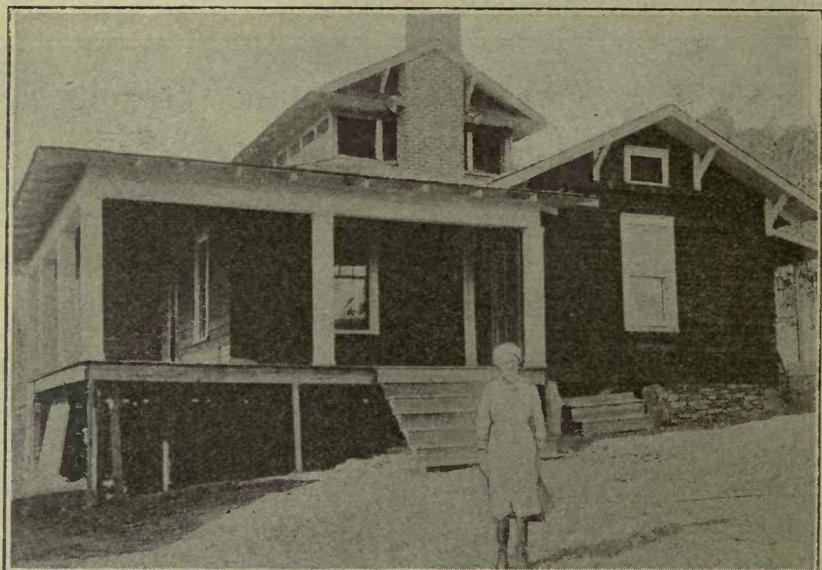

FIG. 42.—A good house, but bare and unattractive for lack of pleasing plantings. Compare with figure 43.

by cutting with a lawn mower every 5 to 10 days, depending on the season. A small area can be cut with a hand mower or a larger one with a horse-drawn mower. If the time necessary to keep a turf smoothly shaven is felt to be greater than is justifiable, an ordinary field mowing machine may be used from once in two weeks to two or three times in a season. Of course this will not produce as nice a turf as would result from the regular use of the lawn mower, but it will keep the lawn neat and reasonably attractive.

If cut every two weeks it may be possible to permit all clippings to remain on the ground. If cut less frequently the clippings will probably have to be removed after each mowing. Live stock should not be turned on the lawn to graze, as they will be likely to eat and trample the shrubbery as well as the grass. It is best to make a clear distinction between the lawn and the pasture extension, separating them by the most inconspicuous fence possible.

For a full discussion of the subject of grading and making lawns, Farmers' Bulletin 494, entitled "Lawn Soils and Lawns," may be consulted.

ARRANGEMENT OF PLANTINGS.

Although the discussion of planting is left until the last, it is not because it is of least importance in the development of an attractive farmstead, but rather to make more clear its true function. There is a widespread lack of appreciation of the importance of the matters already discussed, and a corresponding feeling that no

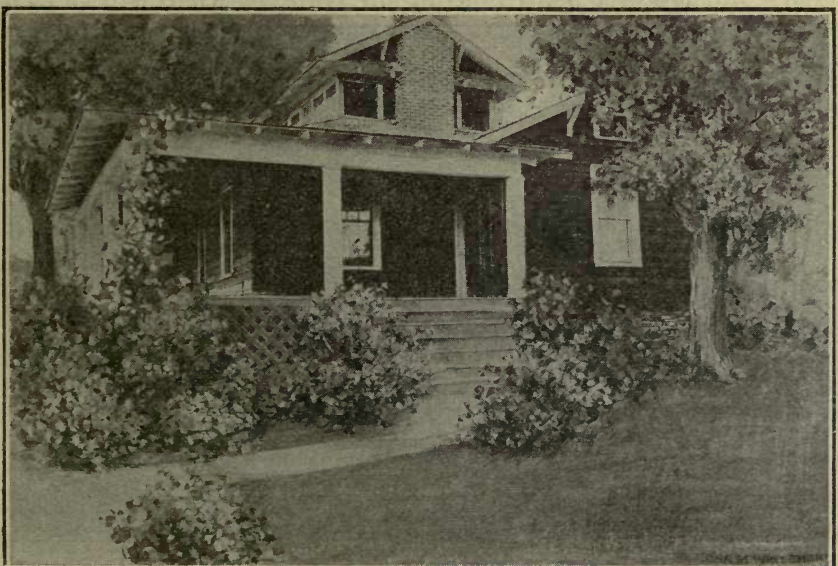

FIG. 43.—The house shown in figure 42 tied to its location by plantings.

matter how poorly arranged and designed a place may be it can be made beautiful by a few flower beds properly located. This idea of the power of plants to beautify is not entirely erroneous, but it is certainly exaggerated. Although they can greatly soften grave faults, they can not hide them. While even a well-designed farmstead is bare and unattractive (fig. 42) until properly united by plantings of trees, shrubs, and flowers (see fig. 43), on the other hand, plants may be so poorly arranged that they fail to add as much to the appearance as they might.

Plant arrangement as well as the design of the grounds may be divided into formal and informal plantings. Formal planting is the arrangement of plants in regular order, either in straight lines or in balanced geometrical designs. This is true whether the effect is produced from the regular placing of individual plants or by massing several specimens of a kind. Such planting is only appropriate in a formal design, which on farmsteads would be in connection with long straight approaches or in formal gardens.

Informal planting is the arrangement of plants irregularly, more or less in the manner in which they are found in native woodlands and thickets, and they may be used singly or in groups of any size with any number of kinds. Planting of this kind is appropriate with either a formal or an informal design and is especially adapted to farmsteads and home grounds.

In formal plantings all the plants must be set and trained to conform to the design (see figs. 4, 16, and 36), while informal plantings

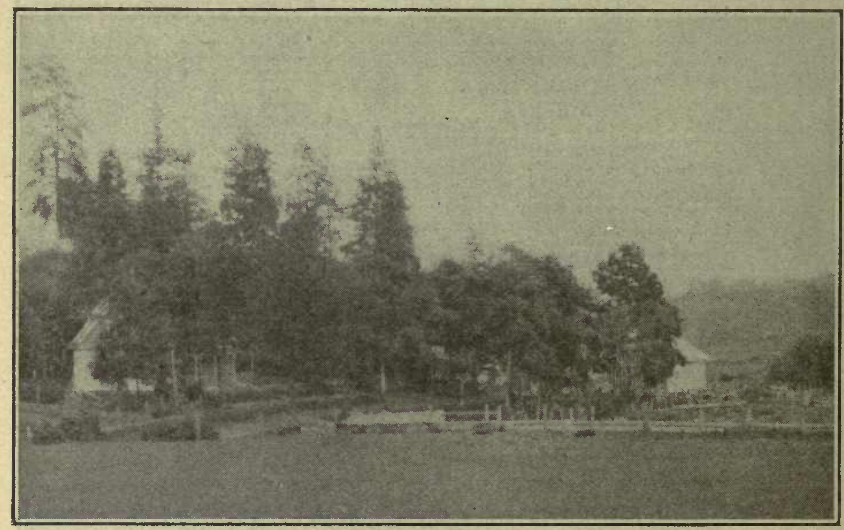

FIG. 44.—Trees about and between farm buildings, giving needed shade and partial seclusion.

should be placed irregularly and trained to bring out the individual characteristics of each variety, so that the result may be as varied, graceful, and natural as possible.

TREES.

The first thought in connection with planting about a farm home turns naturally to trees to provide shade. Old places in the eastern part of the country, both North and South and in the Middle West, and the most homelike and best-developed places in the newer parts of the country have well-grown shade trees about the house and a few in the work yard between the house and barn. (Fig. 44.) Where a farm has been hewn out of a wooded country some fine old trees will usually be found in the stock pastures, and in a few cases of farms on treeless prairies some consideration has been given the live stock by providing trees in the cattle yards. The finer and better the trees about a farmstead the more the attention is likely to be attracted and the greater the impression of homelikeness. A single tree is often sufficient to make a place attractive. (Fig. 45.)

Trees, then, are of great importance in giving an attractive appearance to the farmstead as well as in making it a more enjoyable place in which to live by providing welcome shade and protection from undesirable winds. Trees should be planted with the possibilities of this twofold use clearly in mind. In most of the country north of the 40th parallel there is need of protection from the cold northwest winds of winter and also of shade about the buildings in summer. To meet the former requirement groups or clumps of trees should be so located that they break the force of these objectionable winter winds, while at the same time they occupy the least possible area

FIG. 45.—A single tree is often sufficient to make a place attractive.

of tillable land. In the hilly parts of this region many farm buildings are built in the lee of a rise of ground or close against the side of a hill, so that there is less need of shelter planting. In the eastern and extreme western parts of the country such shelter plantings would be more effective if made largely of evergreen trees, especially those which normally hold their lower limbs, but in the central Prairie and Plains regions the moisture conditions in winter are such that only the hardiest deciduous trees will succeed. Where such shelter is needed the buildings should be so located with respect to it that not only will the trees give the needed protection but also form a background or setting for the buildings from as many points as possible. In addition to the trees providing the shelter, smaller flowering trees can be used in front to give an added interest to the planting. In other large areas, particularly in the western part of the country, where protection is needed from the drying southwest winds, a similar use can be made of shelter plantings. It is often possible to transform an apparently barren waste into a region of productive farms and good homes by first planting shelter belts at frequent intervals (figs. 46 and 50).

Shade trees should be located with a twofold object in mind: (1) To provide shade during the hot season and (2) to make an attractive setting for the house. Although this is the order of importance in the life of the family, the trees would best be located having in mind, first, their value as a setting for the house and then the desirable points at which to provide shade, as they will give shade wherever they are set, but will only make a good setting when properly placed near the building. A sufficient number of trees should be used, however, to make enough shade to invite to outdoor life near the house. Trees should not be planted directly in front of the house,

FIG. 46.—A windbreak that makes living more comfortable.

but they should be placed somewhat to each side so as to make a frame through which a view of a portion of the front is obtained. When the trees are grown they should partially shade the house without entirely covering the front. In the southern part of the country it may sometimes be admissible to plant large trees on both sides of the front, so that when they reach maturity their branches meet. This may only be done if the trees are of a very high headed variety, if they are trimmed so that a good view of the house is obtained beneath them, and if the house faces south. If it faces in any other direction, sufficient shade can usually be provided by some other arrangement. A common fault is to plant too many trees and plant them so close to the house that the shade is too dense and keeps out all the sunshine and much of the air. For this reason as well as for the sake of appearance it is desirable that the trees be so planted that at maturity their branches will not meet across the front of the house. (Fig. 47.)

Fig. 47.—Trees partially hiding a house front.

It is usually desirable to have a large shade tree somewhere near the southwest corner of the house, as protection is most needed from

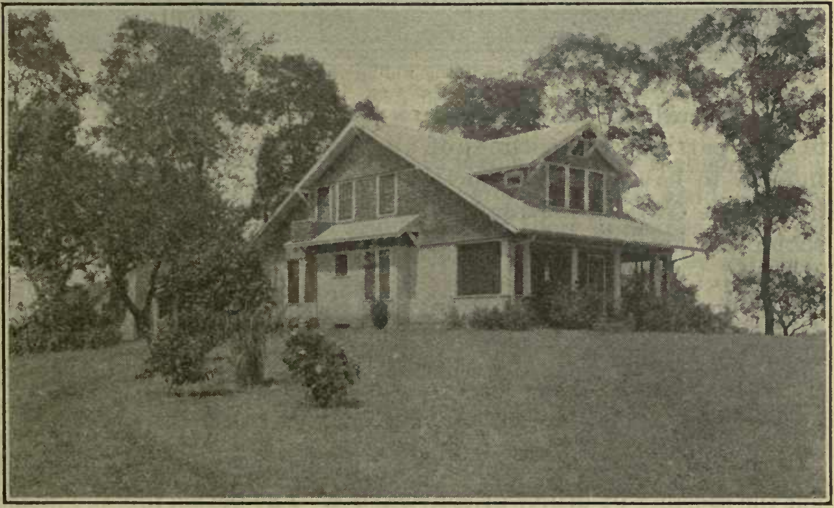

Fig. 48.—Trees at the back of the house form a frame.

the midafternoon sun. In some cases it will be best to place the tree on the west side; in others on the south; and again a group of them about the corner may be better. This may bring the trees to the rear of the house as a background (fig. 48) instead of as a screen in front. Not only should a portion of the front of the house be seen from the principal viewpoint, but there should be an open lawn in front of it. This lawn may be bordered on either side by plantings of trees or shrubs, or both, depending on the size of the place and the character of the development. If the lawn extends to the road, this side may also have trees, under the branches of which views of the house may be obtained. If the house is so far from the road that the lawn does not extend across the intervening space, it is usually inadvisable to inclose the road side of the lawn with trees, no matter how large it may be, as that would entirely hide the house from what

FIG. 49.—Trees partially hiding the front of a barn.

would naturally be the principal viewpoints. Although it is desirable to hide partially the outlines of all the buildings, it takes from the interest to have them completely hidden. It may be advisable to have some trees on the road side of such a lawn, but liberal vistas should be kept open, so that some good views of the house are obtained.

The house and its surroundings, as the home center and the most important unit of the farmstead group, has been emphasized in this discussion. The barns and other buildings should be so planned and located as not to overshadow and take from the interest in the house, even though they may be much larger. By a proper arrangement and the planting of trees and shrubs this can be accomplished without the sacrifice of utility or convenience. The barns, like the houses, usually can be partially hidden from the principal viewpoints (fig. 49) without detracting from their usefulness or wasting land.

It must be recognized, however, that this is not as easy to accomplish without interfering with other vital considerations as is the planting about the house. For example, with dairy and stock barns it is not, as a rule, possible to plant close to the south side, because of overshading the yards in winter, thus depriving the cattle of the full sunshine and also possibly making the yards a mudhole. In many cases the south is the principal viewpoint. Sometimes, however, trees can be planted to overhang the corners of the barn (fig. 49), or if it is not too high can be behind it, partially framing it in foliage. Here, again, care must be used both in selecting varieties and in placing them so that the tops will not interfere with hauling in hay and grain or the trunks interfere with other necessary work.

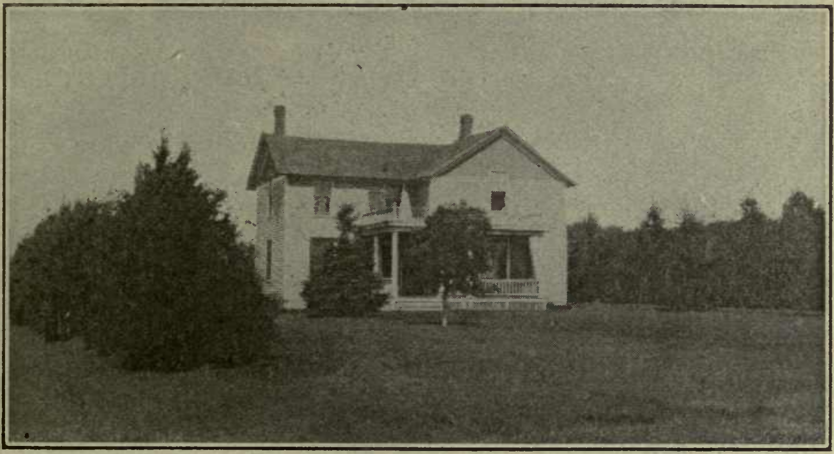

FIG. 50.—A screen of trees protecting the house from objectionable winds. The trees will ultimately form an attractive background for the house.

Paddocks are needed on almost all farms, and the inclusion of a few trees in the lot is helpful to the stock. When such paddocks can be located between the barns and the road their appearance can be greatly improved, while at the same time the land is fully utilized. Orchards frequently can be planned to help in the problem. It is not always easy to find the right solution, but when it is once realized that a barn unsupported by greenery is as much a blot on the landscape as a house so located, efforts will be made to bring about a better condition. Many of the obstacles will be found more imaginary than real, although there will be enough real ones left to require genuine, well-directed, energetic effort in order to solve the problem of making the farmstead homelike.

It is sometimes asked whether trees near a barn may not be dangerous by drawing lightning. They are much more likely to act as a protection, either dissipating what might otherwise be a lightning stroke or receiving the stroke instead of the building.

If well planned, this partial screening of the building can be largely accomplished by trees that are at the same time serving some other useful purpose in connection with the farmstead, such as giving shade in stockyards, pastures, or work yards. The windbreak or orchard may likewise serve a double purpose. In this planting it is not necessary to hide the buildings entirely; the aim is to make them less obtrusive by partially concealing them in foliage. The barns, like the house, should not be surrounded too closely by shade. This fault, however, is seldom found about farm buildings.

FIG. 51.—Evergreens add to the attractiveness of a home in winter.

It is often desirable to screen certain objects from view. (See fig. 30.) Tall plants are sometimes necessary for this purpose, and trees are the logical plants to use. Usually it is best to plant them as for a windbreak (fig. 50), although there are conditions when they may be planted as a grove to equal advantage. Such plantings are most effective when located near the object to be hidden, although there are times when a tree or two near the point of observation must accomplish the purpose.

The way these results are to be attained are among the important details of the preparation of the farmstead plan, and these matters must be considered in connection with the other details. In carrying out the plan one caution needs to be observed; that is, not to plant too many trees nor to have them too close together. When planted, the ordinary tree looks so small that it seems as though it could never fill the space provided. The result is that often more trees are added, thus making them too close when grown. Frequently trees are planted with the expectation of removing some of them, but when the time comes the home makers have become so attached to them that the inclination is to leave them a little longer and a little longer until the proper time for removal is past, the permanent trees are ruined, and still the temporary trees remain.

Except in the extreme South, only deciduous trees should be used for shade close to buildings, so that all the light possible will be available during the winter. At a distance of 75 to 100 feet or more

Fig. 52.—A farm home with good trees but without shrubs still looks bare. Compare with figure 53.

from a building evergreen trees can be used either in some of the groups provided for shade or in the screen plantings. A few evergreen trees or shrubs give an appearance of life to plantings in winter and thus add materially to their attractiveness. (Fig. 51.)

SHRUBS.

Trees alone, without the addition of shrubs and vines, will not give the best possible effect. A farmstead without such additional plantings will still appear bare and unfinished, as shown in figure 52. Many places are already well provided with trees, so it only requires the planting of a few shrubs to make very attractive looking homes. Besides having a portion of their tops hidden by foliage, the farm buildings also need to have much of their foundations hidden. The lines of a building are mostly straight and formal. To make these a part of an informal picture it is necessary to have the

FIG. 53.—Masses of shrubs under the trees take away the bare look seen in the illustration of the farm home shown in figure 52.

straight lines broken and disguised as much as possible. For this reason it is desirable to put masses of shrubs at various points around

FIG. 54.—Buildings look appropriate when they rest in a mass of trees and shrubs. Additional trees are needed near the house as a setting and for shade.

the foundations. (Fig. 53.) These plantings should vary in height and width, so as to hide and modify the straight lines instead of drawing attention to them. On the other hand, portions of the foundation should be exposed and the lawn should be carried directly to these exposed portions, so that the building will appear to be supported. Success in planting is achieved when the buildings appear as though they belonged to the place and fitted naturally together and into the landscape. This is best accomplished by having them rest in a mass of trees and shrubs (fig. 54) while standing firmly on visible foundations. The corners are usually convenient places to plant with tall broad clumps, and these may often be extended into the lawns for a considerable distance. Angles formed by porches, by steps, or by an ell of the building are other points frequently utilized for such groups. Tall groups often may be used also against wide places between windows, while only low ones may be used under

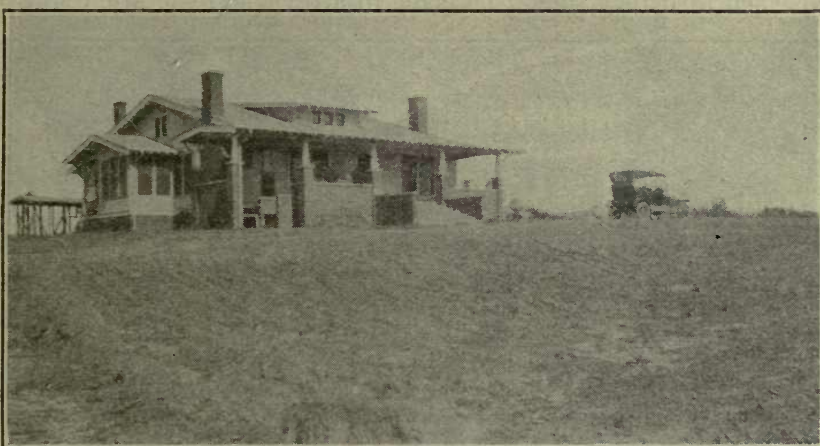

FIG. 55.—At this farm home there is nothing to clearly define the location of the road. Compare with figure 56.

windows. Care must be taken not to have the different groups too much alike in breadth, height, and texture of foliage, or in "expression," as it might be called.

To emphasize the feeling that the house belongs to the surroundings, the appearance of definite boundaries to the lawns should be avoided as much as possible. On most farms it is necessary to limit rather definitely the ground devoted to the home, but this limitation should not be made any more emphatic than can be helped. As already suggested, it is often possible to have the pasture or a meadow adjoin the lawn with an inconspicuous fence between. Another help to this impression is to disguise the actual boundaries by more or less continuous but irregular plantings along them. Where it is possible, distant views or near-by landscapes should be made to appear as though they were a part of the grounds. Much can be accomplished to this end by proper location of the tree and shrub groups on the boundaries of the home lot. Openings should be left in the plantings to expose the desirable view from the windows of the most-used rooms, the porches, or portions of the lawn, and plants of suitable size and height should be used to hide the less desirable outlooks. If there be a broad view, it is usually made more interesting by being divided into parts, as 30°, or one-twelfth of the circumference of a circle, is about as much as the eye can see at one time, and this is as much as should be included in a single view of a distant landscape. If it is necessary to inclose the home lot, the most inconspicuous wire fence possible is desirable, although sometimes a fence covered with vines or a hedge is better. As fences or hedges accentuate the boundaries, they usually should be avoided and when used they should be made to attract as little attention as

Fig. 56.—Shrubbery on the grounds of the farm home shown in figure 55 indicates the location of the road and provides a reason for the turns.

possible. Their tendency is to give a "penned-up" feeling rather than the feeling of freedom that especially should be associated with the country home.

Shrubbery is also used to help outline the course of walks and drives and give an apparent reason for the turns (compare figs. 52 and 53; also figs. 55 and 56), and to make the surface less conspicuous by hiding it from many points. Such shrubbery must not be so high that persons in automobiles or other vehicles can not see others approaching around turns or so that vehicles and pedestrians are hidden from one another at the intersection of walks and roads.

Besides being used on the boundaries to screen less desirable views, shrubs are also useful as screens within the grounds either to hide objectionable views or to give privacy (figs. 57 and 58). It is sometimes well to shut off views between the barns and the house or between buildings and the highway, or even to give privacy to a work yard or a flower garden. Shrubs will often do as well as trees for a

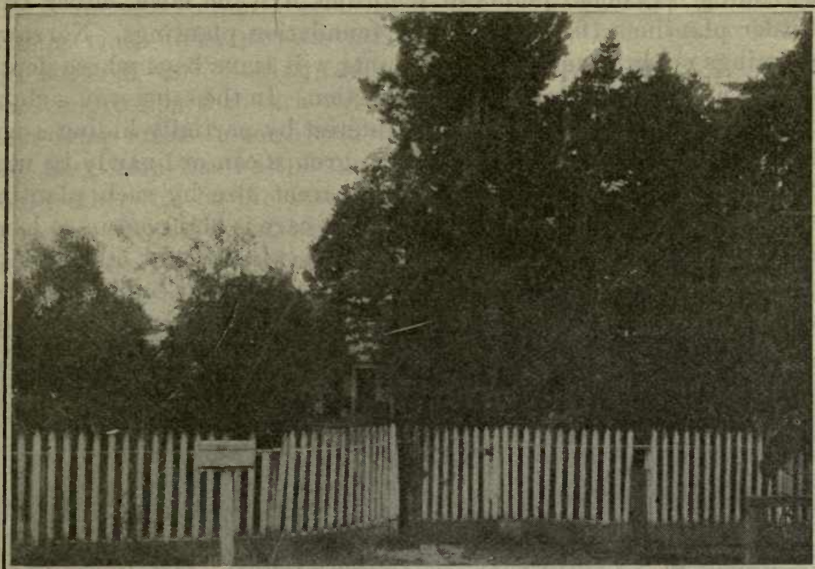

FIG. 57.—A screen to give privacy. Figure 58 shows what is behind the screen.

FIG. 58.—The farmhouse behind the screen shown in figure 57.

low windbreak. Besides the utilitarian screening just outlined, interest may be added by partially hiding one part of the grounds from another, simply to pique curiosity. If the whole of an object is seen at one time curiosity is satisfied and interest in it is gone, but if part is hidden it invites exploration. This is another reason for extending occasional points of plantings into the lawn, either from border plantings (fig. 59) or from foundation plantings. Narrower plantings on either side of such points will leave bays whose depths can not be seen without further inspection. In the same way a clump may be used occasionally to excite interest by partially hiding a portion of the grounds. Not many such groups can ordinarily be used. There is danger of dwarfing the apparent size by such planting, especially on small grounds, unless great care is observed in so locating the shrubs that they do not obstruct what would otherwise be good vistas. Such clumps must have some apparent connection with other plantings. They should either seem to be a part of the border

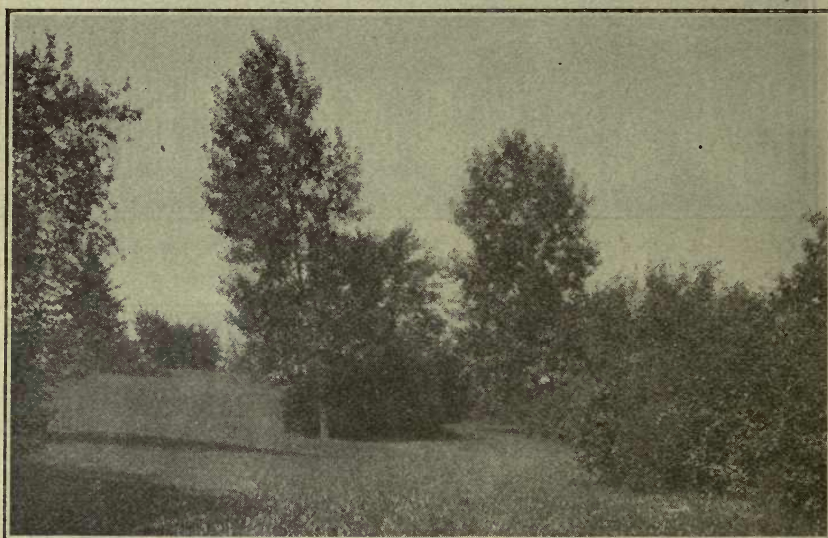

FIG. 59.—Promontories on border plantings.

plantings, of the base plantings, or of the plantings along the drives and walks. A bed alone in the middle of a lawn detracts from the appearance instead of adding to it.

An individual plant seldom can be used to advantage. Where a small mass is desired and a shrub has the size and habit required to fill that particular need, then a single specimen may be used. Occasionally a shrub can be set just in front of massed plantings in order to give variety, but as a rule this result can be obtained better by combining the shrubs differently in the groups.

VINES.

Vines are among the most useful plants for "tying" buildings to their surroundings. There is a freedom and grace about their growth that helps to relieve the formality of buildings or fences better than almost any other plants. (Fig. 60.) Care in their selection is necessary, however, as there are disadvantages in the use of some vines under certain conditions. On brick and stone buildings some of the clinging vines are most appropriate. An erroneous impression that such vines are injurious to the walls or make them damp exists in some quarters. This is true to the extent that they may keep the wall shaded and cool later in the spring than would otherwise be the case and so cause plaster applied directly to such walls to "sweat" in little used and insufficiently ventilated rooms. The difference between vine-covered and noncovered walls is in the time when this sweating process takes place. The leaves

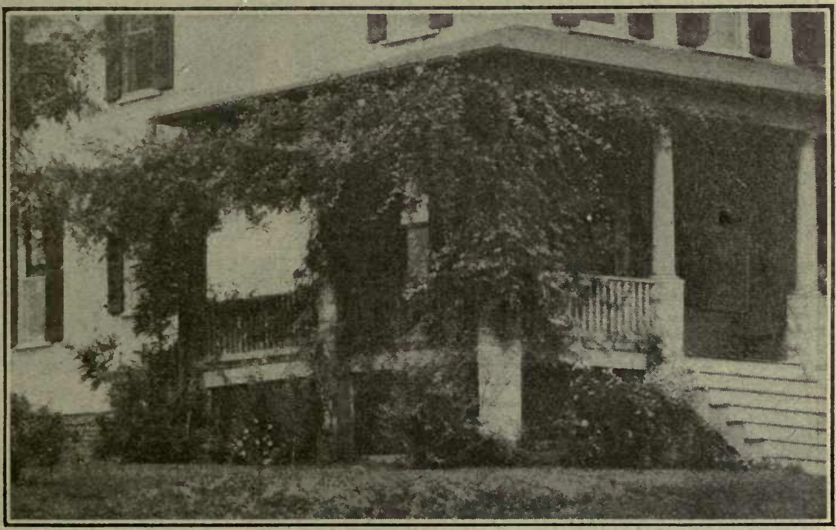

FIG. 60.—Vines help to relieve the formalities of buildings.

of such vines have somewhat the effect of a roof in keeping much rain from reaching the wall, and the aerial rootlets have a tendency to absorb the moisture that might get under the leaves. Where the construction is defective they may at times find crevices between bricks or stones and thus reveal poor workmanship, but rain and frost will do that as surely as the vines. On wooden buildings the problem is somewhat different. Many vines that climb by twining will force their way through any joint that is not perfect and then by continued growth force the woodwork apart. Many other vines do not have this injurious effect and can be used appropriately.

The great problem is so to train the vines that they may be removed to permit proper painting of the woodwork when that is necessary. This may be done by means of a trellis hinged near the ground or a chicken wire placed over hooks at the highest point, so that it may be removed. A trellis can be made of chicken wire on a pipe frame that will keep vines entirely away from woodwork. The thought is sometimes expressed that vines cause woodwork to rot. This is true if they are permitted to become so thick as to prevent proper ventilation and timely painting. Hot sunshine, however, is one of the most destructive forces in the life of paint. Vines by their shade help to preserve paint instead of destroying it.

Besides being appropriate on porches and on trellises against frame houses and on the walls of brick or stone houses, vines are

FIG. 61.—Scarlet sage in front of hemlocks.

also appropriate on fences, arbors, and pergolas, or on summer houses connected with the pleasure grounds or outdoor living sections of the grounds.

HERBACEOUS PLANTS.

Besides the plants already suggested for the principal plantings, the herbaceous perennials and the annual flowering plants offer a large amount of material that is very useful to add bloom and color where these may be lacking. Little bays or pockets may be left between the shrubs, especially near the borders of the clumps, that can advantageously be filled with hardy perennial plants that give bloom at a time when the shrubs are lacking in bright colors. As a rule the period of bloom of these plants is not much longer than that of the shrubs, but many have extremely bright colors and these can be placed between the other plants where they will not take much room and will help to make a continuous picture. Most perennial plants will last three years or more without need of lifting and resetting. The spring-flowering bulbs, such as tulips, hyacinths, and narcissi, can also be scattered among the shrubs and be permitted to remain there and bloom for several years. Of these the narcissi are much the best adapted to this treatment.

Annual flowering plants can also be scattered at various points along the shrubbery beds and so provide color at a time when it is almost entirely lacking among the other plants. The tender bedding plants, such as cannas and geraniums, may also be appropriately used in the way shown in figure 61, where plants of scarlet sage have been used in front of some hemlocks, making a striking combination that could easily have been overdone. Such material should be used in moderation and in small clumps, never as continuous borders either to shrubbery beds or to beds along the house except in formal gardening. Beds of such material should not be planted in the open lawn. If that sort of planting is desired a formal garden should be provided where the planting can be done appropriately.

Tenants leasing from year to year or others expecting to be on a farm for only a few months can bring about much improvement by planting annuals and tender bedding plants in the manner described for shrubs.

PLANT MATERIAL.

In planting the farmstead the particular plants used, if hardy and adapted to the region and locality, are of less importance than the general effect of the mass. The expression of the mass, however, is dependent on the combined effect of the characters of the plants composing it. There are great differences of expression between the exclamatory or "look-at-me" impression created by the Lombardy poplar and other tall slim plants and the sympathetic and almost mournful impression given by drooping plants, like the weeping willow; between the sturdy self-reliant attitude, typified especially by the white oaks and live oaks, and the dependent or clinging attitude expressed by vines; between the formal expression of symmetrical rigid-growing plants, like the firs and spruces, and the informal expression of the tamarisk; and between the heavy effect of plants with large dark leaves and the airy effect of plants with small light-green leaves.

Plants with great differences of expression should not be used too close together, but should be united by those with intermediate characters. The lines of the different parts of the mass should flow into one another without too great contrasts. Transitions in color and texture should also be gradual. The more unusual the characters of a plant the greater is the need for carefully placing it where it will be most pleasing.

Plants selected for home-ground ornamentation should be hardy in the region, should be comparatively free from attacks by insects and diseases, should have a reasonable quantity of foliage that is not liable to drop from slightly adverse conditions, especially weather conditions, and should be of the proper size, habit, and texture for the location; that is, where a tall upright shrub is needed a tall spreading one should not be used. Most of the planting should be of comparatively few kinds, although a few specimens of unusual sorts will give variety and add a certain amount of interest. The characters of plants that make them valuable for adornment are (1) foliage, (2) winter effect, and (3) flowers. The importance of foliage is due to its permanency, lasting from five months to a year, depending on the type of plant, the latitude, and the elevation, while the period of bloom is short, usually not more than two weeks.

Next to foliage in importance comes the winter effect. Taking the United States as a whole the average time that deciduous plants are without foliage is at least five months. During this period the farm home is occupied as continuously as in summer, and the surroundings should be as attractive as possible. Evergreen shrubs, both coniferous and broad leaved, maintain a color throughout the winter not otherwise obtained. Used in moderation, they are a distinct addition at this season. On the other hand, many deciduous shrubs have attractive winter characters, the most striking being bright-colored berries. Then there are barks of many shades of brown and gray, with some of bright red, green, and yellow, that if properly arranged make pleasing contrasts and add to the winter beauty. The short blooming period of the average shrub makes flowers the least important of the characters to be considered. In spite of this the color, character, and time of blooming should be considered as well as the behavior of the dying flowers, whether or not they fade to a conspicuous and undesirable color and hang on unduly or pass away without a distinctly unsightly stage.

The different kinds of plants should be selected so that they will give bloom through as much of the season as practicable, thus affording something of special interest as continuously as possible. The bulk of the planting, however, should be of a few species. Eight to a dozen kinds are enough for an ordinary place. With this small number, selected as far as practicable to bloom at different seasons, there is little danger of getting color combinations that will not harmonize. Where especially bright colors are selected, others should not be chosen for growing next to them during the same season unless they harmonize. Near brick buildings, or buildings painted with bright colors, care must be exercised in selecting shrubs with colored flowers. White flowers are always safe and can be used to help in giving other flowers an appropriate setting. A plentiful use of the different greens or a mixture of many colors is also safe. It is only

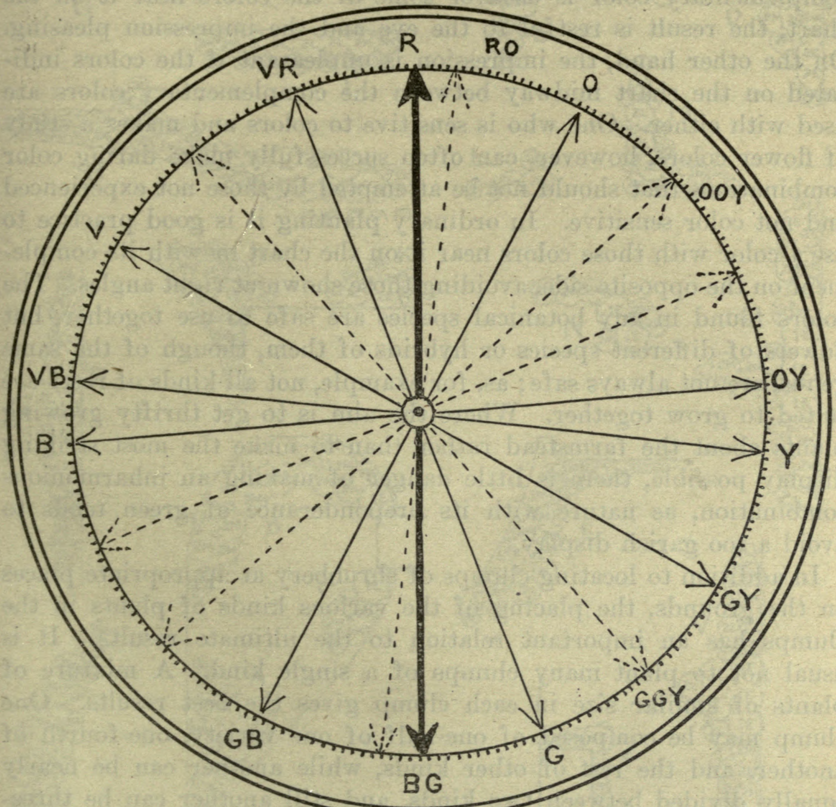

FIG. 62.—A chart showing the appropriate color combinations for highly colored flowers. Colors immediately adjacent to one another on the chart, or those opposite or nearly opposite one another, are apt to harmonize and are therefore safe to use together. Those at right angles to one another are liable to be discordant, and should not be used together by those not thoroughly familiar with color harmonies and the possibilities of color combinations. *B*=blue, *G*=green, *O*=orange, *R*=red, *V*=violet, *Y*=yellow.

when one or two colors are selected for use in quantity that danger of lack of harmony arises.

The reason that white is a safe color to use is because the human eye can observe it with least fatigue. It is composed of a mixture of the colors of the rainbow. Theoretically, each of the rainbow colors can be combined with some other color and produce white, although in practice it is a dirty white or light gray. Two colors that can be combined in this way are spoken of as "complementary colors" and are shown opposite one another in figure 62. If a bright color is looked at intently for several seconds and then the eyes are closed the first impression is that of the complementary color. In practice, it is found that if with a large mass of bright color the complementary color is used or some of the colors near it on the chart, the result is restful to the eye and the impression pleasing. On the other hand, the impression is unpleasant if the colors indicated on the chart midway between the complementary colors are used with either. One who is sensitive to colors and makes a study of flower colors, however, can often successfully make daring color combinations that should not be attempted by those not experienced and not color sensitive. In ordinary planting it is good practice to use a color with those colors near it on the chart or with its complement on the opposite side, avoiding those shown at right angles. The colors found in any botanical species are safe to use together, but flowers of different species or hybrids of them, though of the same genus, are not always safe; as, for example, not all kinds of roses are suited to grow together. Where the aim is to get thrifty growing plants about the farmstead rather than to make the most striking display possible, there is little danger of making an inharmonious combination, as nature with its preponderance of green tends to avoid a too garish display.

In addition to locating clumps of shrubbery at appropriate places on the grounds, the placing of the various kinds of plants in the clumps has an important relation to the ultimate results. It is usual not to plant many clumps of a single kind. A mixture of plants of similar size in each clump gives the best results. One clump may be composed of one-half of one variety, one-fourth of another, and the rest of other kinds, while another can be nearly equally divided between two kinds, and still another can be three-fourths of one kind and the remainder of any other combination. Where a large quantity of one variety is used in a clump, it is well to have at least a few of the same plants in some of the near-by groups. In nature, trees and shrubs are mostly found in large quantities, either almost alone or well mixed with other plants. As the boundaries of these areas are reached, the plants are found in more or less scattered clumps, until the place is reached where there are none. In a similar way the plantings should be in comparatively large masses with scattered plants in other near-by clumps, as shown in figure 63, where the arrangement is indicated by different numbers for different kinds. The plants should be set at irregular distances apart, so as to avoid being in lines in anv direction.

By making a few clumps largely of one kind of shrub and by scattering plants of it in others, the impression may be given of the yard being full of this plant when in the height of its bloom.

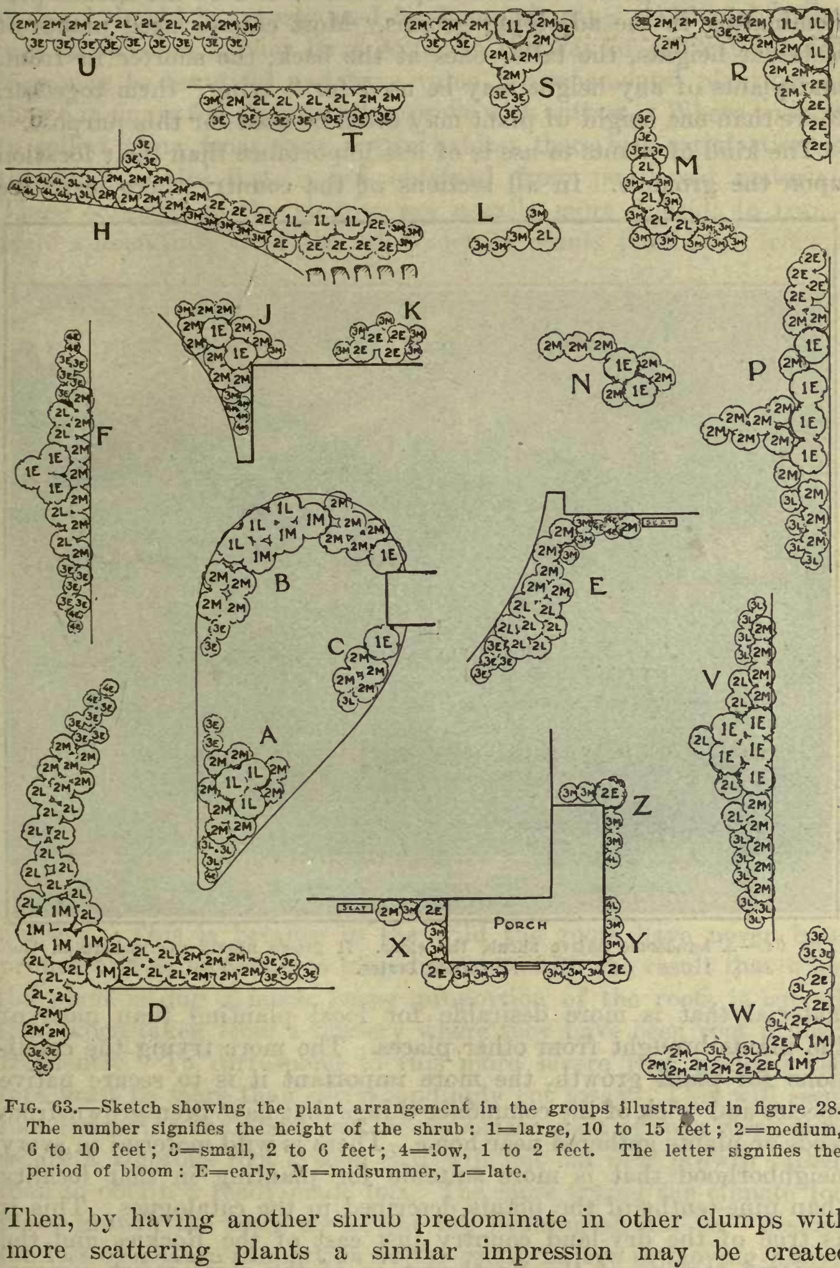

FIG. 63.—Sketch showing the plant arrangement in the groups illustrated in figure 28. The number signifies the height of the shrub: 1=large, 10 to 15 feet; 2=medium, 6 to 10 feet; 3=small, 2 to 6 feet; 4=low, 1 to 2 feet. The letter signifies the period of bloom: E=early, M=midsummer, L=late.

Then, by having another shrub predominate in other clumps with more scattering plants a similar impression may be created for another plant at another season. Other kinds can then be restricted to limited portions of the grounds. If for any reason it seems desirable to use a certain shrub only in one particular clump, this clump can be made to appear to belong to the rest of the planting by including in that mass a specimen or two of the shrubs predominating in the adjoining groups. Most clumps need plants of different heights, the taller ones at the back, the shorter in front, and plants of any height may be used for "tying" them together. More than one height of plant may often be used for this purpose.

The kind of plants to use is of less importance than their location upon the grounds. In all sections of the country there is native

Fig. 64.—A handsome native shrub, the elder. It grows nearly everywhere in the United States.

material that is more desirable for local planting than most of the plants brought from other places. The more trying the conditions for plant growth, the more important it is to secure native species and stock of the commoner things that have been grown from seeds or plants gathered near home. There is wild material in every neighborhood that is more suitable for planting in that locality than nine-tenths of the plants described in the catalogues. This is as true of the dry-land country just east of the Rockies and the semiarid regions of the Southwest as of the more moist regions. Search along the streams, on the hillsides, on the plains, in the woodlands, draws, arroyos, or canyons will reveal the attractive things that are close at hand. Europeans recognize the value of many of these plants, collect them and grow them a few years, and then introduce them to us. The common wild plants of any neighborhood should be largely used for home planting. Although many may be so common they have gotten in the way of cultivation, still they may be beautiful and have value for ornamental planting, as shown in figure 64. Nearly all improve with culture. Where possible to collect them from their native habitat there is a satisfaction in the final results that is not obtained from purchased material. Those collected in the vicinity are usually more difficult to transplant successfully than the same sort of plants purchased from a

FIG. 65.—Shrubs with temporary plants set between.

nursery. This is because in the wild the roots have never been pruned and so have run to long distances, with the result that when the plant is dug a much larger proportion of the roots is cut off than when taken from a nursery where they have been root pruned frequently. To correspond to this more severe root pruning the tops must be more than correspondingly cut away. This will seem like destroying the plant, but the important part of such work is to secure a vigorous root system that will put out new growth rather than to obtain a ready-made top. The more trying the climate for plant growth the more severe the top pruning should be. Besides the loss of a large proportion of the roots, failure in moving native plants comes from lack of sufficient care in keeping the roots moist from the time they are dug until they are replanted. The roots should be kept covered with wet packing material from the time they are exposed to the air until they are again set in the ground.

If the plants are to be purchased, a reliable nurseryman, located where the climatic conditions are as near like the local conditions as possible, should be selected. The stock should have been produced from seeds or cuttings grown near home rather than from plants grown under different climatic conditions. The reason for this is that the plants will be likely to be hardier and be better adapted to the local conditions. A partially tender plant is always unsatisfactory.

There are two methods of setting shrubs for ornamental effect: One is to set them as far apart as they should be when they reach maturity, and the other to set them more closely and from time to

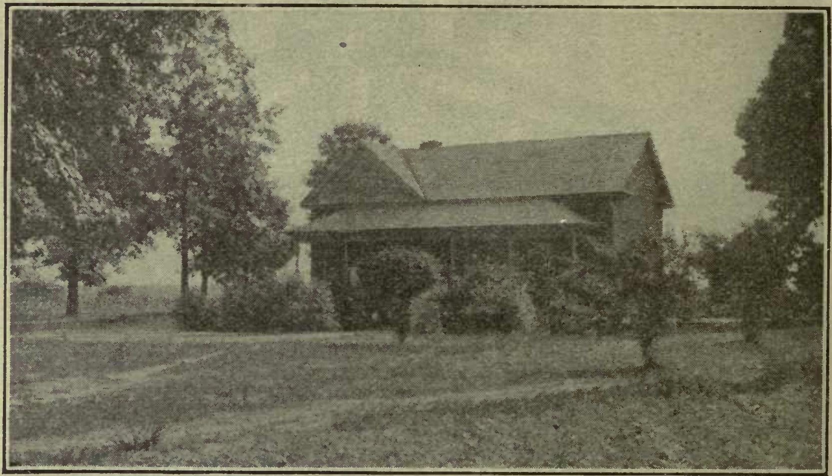

Fig. 66.—Shrubs help to make a house seem homelike. Although these shrubs are massed too much in front of the house they add greatly to its appearance.

time remove some of them. With the first method (fig. 65) it is necessary to use annuals or perennials between the shrubs for several years in order to have the beds and clumps filled. This usually does not entail much extra work, as such plants are frequently wanted at some point on the grounds or in the garden for their bright summer effect. The difficulty with the second method is that the thinning is not likely to be done as soon as it should be (fig. 66). Where only part of the spaces set aside for planting are ready, the plants for all the spaces may often be put where the beds are prepared, and then the extra plants can be taken to the place designed for them as soon as the beds are ready. In this way, too, it is possible to start with smaller, cheaper plants than where an immediate result is desired with permanent plants only.

After trees and shrubs are planted they will need hoeing and manure for two or three years until well established, when they can, for the most part, take care of themselves, unless rapid growth is a consideration; then the manuring and cultivation should continue. After becoming established they will need no pruning further than to remove dead or broken wood. If a mistake is made in the original selections, so that plants of a wrong size, habit, or texture are placed at any point, no hesitation should be felt about correcting the error by removing them and putting appropriate plants in their place.

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. March, 1920

A HOME and its surroundings must be attractive in order to be most uplifting to the family, visitors, and passers-by.

Farmsteads especially need attention in order to secure satisfactory conditions. The farm home and the farm business are so closely related that the success of the latter is reflected in the appearance of the former.

All the buildings with their immediate surroundings must be considered. The roads and walks; the home vegetable, fruit, and flower gardens; the lawns; and the ornamental plantings are also important factors in determining the plan.

Each building needs sufficient land about it to give it a proper appearance and provide the necessary yards or work room, and each should be so located with respect to other buildings as to facilitate the work of the farm.

Roads and walks should be limited to the number necessary to facilitate daily traffic.

Vegetable, fruit, and flower gardens must provide liberally for the family needs.

The lawns should be so located and of such size as to give a pleasing setting for the home, but not large enough to make their care burdensome.

Suitable plantings are necessary to unite the parts of a farmstead into a pleasing, homelike whole. Trees are used for windbreaks, as frames for the buildings or a background for them, and to give shade. Shrubs are needed in abundance to hide partially the foundation lines of buildings, support their corners, give reasons for turns in drives or walks, and to screen unsightly objects. Native trees and shrubs and those known by trial to thrive in the locality are the best to use.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 934

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER June 16, 1921

DAMPING-OFF IN FOREST NURSERIES.

By Carl Hartley, formerly *Pathologist, Office of Investigations in Forest Pathology.*

CONTENTS.

DAMPING-OFF IN GENERAL.

Damping-off is the commonest English name for a symptomatic group of diseases affecting great numbers of plant species of widely separated phylogenetic groups. It is commonly used for any disease which results in the rapid decay of young succulent seedlings or soft cuttings. Young shoots from underground rootstocks may also be damped-off before they break through the soil (66).[1] The same term is even used for diseases affecting the prothallia of vascular cryptogams (2). The name apparently originated in the fact that the disease is usually most prevalent under excessively moist conditions. In those cases in which the disease becomes serious without the presence of unusual amounts of moisture the term is a misnomer. It is, however, so thoroughly established in practical use that it would be impossible, even if desirable, to establish any other name.

[1] The serial numbers in parentheses refer to "Literature cited," at the end of this bulletin.

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While the parasites reported as causing damping-off are probably not as numerous as the host species which are subject to it, a considerable number are known. Two quite different types of damping-off parasites may be recognized. In the first type we have fungi, such as *Pythium debaryanum* Hesse and *Corticium vagum* B. and C., soil inhabiting and primarily saprophytic, which attack a great variety of hosts, and are at least better known, if not more destructive, as damping-off organisms than as parasites on older plants. They are specialized as to the type and age of tissues which they attack rather than as to host. The second type includes fungi less common as saprophytes and with a relatively limited, sometimes very closely limited, host range. *Phoma betae*, the systemic parasite of sugar beet (37), is an excellent example of the host-specialized parasite, transmitted in the seed and capable of seriously injuring various parts of the older plant at different stages of growth as well as attacking seedlings.

Most damping-off parasites are intermediate in habit between the extremes of these two types. Of those which are somewhat host specialized, the following may be mentioned:

- *Phomopsis vexans*, the cause of foot-rot of eggplant, reported by Sherbakoff (128) as a frequent cause of damping-off of this host and believed to be carried on seed.
- *Gibberella saubinetii* (Mont.) Sacc. (29) and the imperfect fungi which kill grain seedlings as well as cause diseases of the older plants (80; 126, p. 218). Species of Gloeosporium and Volutella named by Atkinson (2, p. 269; 52) as able to kill seedlings or cuttings of particular host plants.
- *Glomerella* (*Colletotrichum*) *gossypii*, described by Atkinson (1) and Barre (4) as likely to cause damping-off of cotton (112).
- *Fusarium lini*, the flax parasite, reported by Bolley (14) as destructive to young seedlings.
- *Phoma lingam*, the cause of black-leg of cabbage, at least under inoculation conditions able to kill quickly seedlings of cabbage and other crucifers (72).
- *Peronospora parasitica* (Pers.) De Bary, a downy mildew attacking cabbage and various other crucifers, reported as killing thousands of very young cabbage plants in Florida seed beds (41).
- The entomophthoraceous *Completoria complens*, on fern prothallia (1; 87, p. 203).
- *Bacillus malvacearum*, a parasite of the leaves of cotton plants, which can also cause damping-off of its favorite host (113) and the bacteria from diseased cucumber plants with which Halsted (53) caused typical damping-off of cucumbers.

Damping-off fungi with wider host ranges include *Phytophthora fagi*, *Aphanomyces levis* (100), *Rheosporangium aphanidermatus* (38, 39), *Botrytis cinerea*, and certain Fusaria. The so-called propagation fungus, "vermehrungspilz," a sterile damping-off mycelium which Sorauer (133, p. 321) believed related to Sclerotinia and for which Ruhland (115) has erected a new genus, considered by both authors the most serious enemy encountered in growing softwood cuttings in Germany, if distinct would be a further addition to these generalized parasites. However, it is now believed (34) to be identical with *Corticium vagum.* Common generalized parasites of older plants, such as *Sclerotinia libertiana*, *Sclerotium rolfsii* (129), and *Thielavia basicola* (47), capable of attacking roots or other parts of older plants of numerous species, may also be considered among the damping-off fungi when they cause the death of small seedlings, as occurs, for example, in attacks by *Sclerotinia libertiana* on lettuce (20, p. 28) and celery (103, p. 536) in seed beds. Further study will probably result in multiplying almost indefinitely the number of more or less important damping-off parasites, both of the specialized and unspecialized groups, although the most important of the latter type are probably already known.

Most of the references in literature to damping-off describe its occurrence in truck crops and the losses caused in these crops. According to Halsted (53, p. 342), weed seedlings are also very commonly attacked. Duggar (33) names lettuce, celery, cotton, sugar beet, cress, cucumber, and sunflower as especially susceptible to injury by the two most important damping-off organisms. Except for the plant species in which damping-off by seed-carried parasites is common, it appears that the economic damage from damping-off is serious only with plants whose culture involves the raising of the seedlings in crowded seed beds for subsequent transplanting. For example, tomatoes do not ordinarily suffer from damping-off in the field (70), but the growing of seedlings in flats for subsequent transplanting is sometimes seriously hampered as a result of the prevalence of damping-off. This same principle holds in general for trees. Broad-leaved trees, which are usually not as crowded in the seedling stage as are the conifers, seldom give rise to complaint on the score of damping-off. The conifers, subject to serious losses in nursery beds, are not believed to be greatly affected in this country by the better known types of damping-off under forest conditions (68) except in the less common cases in which seedlings come up in close groups from squirrel hoards, artificial seed spots, or similar sources.

A considerable number of broad-leaved trees have been reported at one time or another as injured by damping-off, though complaints of commercially serious losses are not common. The cases which have come to the writer's attention are listed below:

Cause not determined:

- Orange (43, 108).
- Olive, in greenhouse at the University of California.
- Russian wild olive (*Elaeagnus* sp.), serious at an Iowa nursery; oral report by Mr. C. R. Bechtle, formerly of the United States Forest Service; at another nursery in the same region this plant was reported as very little subject to injury.

Cause not determined—Continued.

- Magnolia (31), troublesome if the pulp is not washed off the seed before planting.
- *Eucalyptus* spp. (88, p. 45; 131), serious under moist conditions.
- *Betula* spp. Communication by Dr. Perley Spaulding, of the Bureau of Plant Industry; found especially susceptible in a Pennsylvania nursery.
- Carob, at United States Plant Introduction Garden, Chico, Calif. Dr. Mel T. Cook states that damping-off is more serious in carob seedlings if the seed is removed from the pod than if pods and seeds are sown together.
- *Robinia pseudacacia* (13).
- Apple, in greenhouse at the Michigan Agricultural College.

Sclerotinia sp. (Europe):

- Betula (79), a disease of seed and germinating seedlings.

Phytophthora fagi (Europe):

- Fagus. Hartig (59) and many other writers; seriously affected, even in forest.
- Platanus (15).
- Acer (15), *A. platanoides* and *A. pseudoplatanus* (86, 104).
- Robinia (59, 73).
- Fraxinus (73).
- Acacia (59).

Cercospora acerina (Europe):

- *Acer platanoides* and *A. pseudoplatanus* (58).

Pythium debaryanum:

- *Tilia europea* and *T. ulmifolia* (137), serious.
- Robinia (75, p. 13–14), killing germinating seed.
- Catalpa (126).

Rhizoctonia:

- Citrus seed beds (130); much loss.
- Catalpa (126).

Botrytis cinerea:

- Catalpa (126).

Fusarium sp.:

- Citrus seed beds (130); much loss.

The sugar beet is apparently the only plant whose damping-off diseases have been investigated with any degree of completeness by modern methods. While there is a great mass of literature on damping-off, it is mainly descriptive and on control measures. Most of the reports of the causal relation between the different fungi and the disease in the various host plants have been based on demonstrations of the presence of the fungus in diseased seedlings. In a great number of these cases identification has been doubtful. Even when a fungus is known to belong to a parasitic species, it is by no means certain that the mycelium found belongs to a parasitic strain. It has been found, for example, that only part of the strains of *Corticium vagum* occurring in sugar beets are able to attack that host vigorously (38, p. 154). Similar data for pine appear in figures 1 and 2. Furthermore, even parasitic strains of several of the damping-off organisms are so widely distributed as saprophytes that one of them might easily get into a killed seedling after some other parasite had caused its death. Not only in the case of seedlings killed by fungi like *Peronospora parasitica*, but in

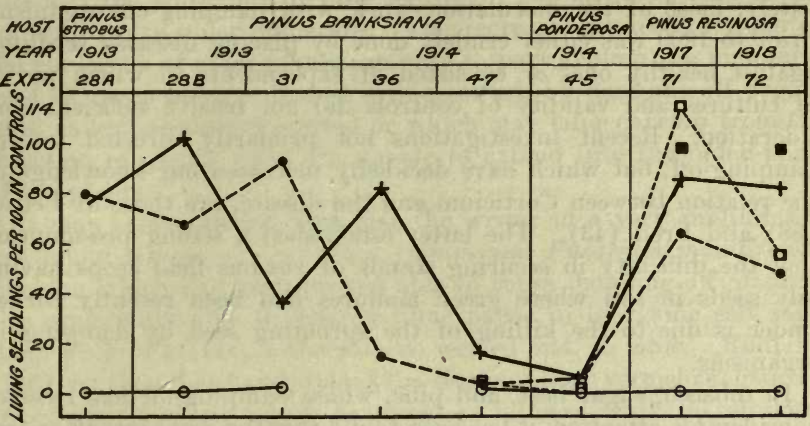


FIG. 1.—Diagram showing the relative activity of different strains of *Corticium vagum* in inoculations made at the time of sowing the seed. In experiments Nos. 36, 45, and 47 the values are plotted for the number of seedlings appearing above the soil. For the other experiments the number of seedlings surviving at the close of the experiment have been taken. Explanation of symbols: ○=Strain 147, from spruce seedlings, Washington, D. C., 1910; +=strain 50, from pine seedlings, Nebraska, 1909; □=strain 233, from *Elaeagnus* sp., Kansas, 1913; ■=strain 230, from the same lesion as strain 233; ●=strain 183, from bean, New York, 1910.

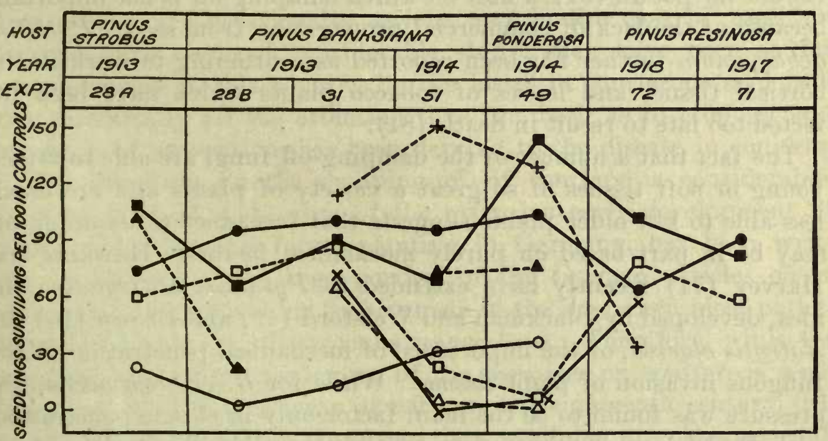


FIG. 2.—Diagram showing the relative activity of different strains of *Corticium vagum*, as indicated by the number of seedlings surviving in inoculated soil. Explanation of symbols: ●=Strain 189, from sugar beet, Michigan, 1910 (light-brown mycelium with few sclerotia); ▲=strain 211 and △=strain 212, from sugar beet, Colorado, 1910; ■=strain 186, from potato, Ohio, 1910; □=strain 187, from potato, New York, 1910; +=strain 205, from Douglas fir, Colorado, 1911; ×=strain 192 and ○=strain 206, from pine, Nebraska, 1911.

cases of true damping-off produced by the rotting type of parasite, much of the rapid decay of the seedling after death is brought about by bacteria and fungi other than the one causing death.

Inoculation experiments are therefore probably even more necessary in damping-off investigations than in studies of most other diseases in order to demonstrate etiological relationships. Unfortunately, most of the inoculation work with damping-off organisms prior to 1900 was either crudely done by placing diseased seedlings against healthy ones or consisted of experiments in which purity of cultures and validity of controls did not receive sufficient consideration. Recent investigations not primarily directed toward damping-off, but which have decidedly increased our knowledge of the relation between Corticium and the disease, are those of Peltier (98) and Fred (43). The latter established a strong presumption that the difficulty in securing stands of various field crops having oily seeds in soil where green manures had been recently turned under is due to the killing of the sprouting seed by damping-off organisms.

In tobacco, sugar beet, and pine, whose damping-off has received considerable attention, it has been found that the damping-off proper is commonly preceded by the killing of many of the sprouting seeds in the soil (38; 68, p. 522; 81, p. 5) and followed, after the plants become too large to be killed by the damping-off organisms, by root sickness and the death of small roots (38, p. 161; 64; 100). This latter has been reported also as a serious matter in the case of *Corticium vagum* for potato (51), a host on which damping-off is not important because of the lack of commercial propagation from seed. *Pythium debaryanum* further has been reported as continuing to work in the cortical tissues and leaves of tobacco plants which have been infected too late to result in death (81).

The fact that a number of the damping-off fungi are able to attack young or soft tissues of so great a variety of plants and are much less able to kill older plants suggests that resistance to damping-off may be in part based on purely mechanical factors. Hawkins and Harvey (71) recently have extended to *Pythium debaryanum* the idea, developed by Blackman and Welsford (12) and Brown (16) for *Botrytis cinerea*, of the importance of mechanical penetration in the fungous invasion of plant tissues. While for *B. cinerea* mechanical pressure was found to be the main factor only in cuticle penetration, with *P. debaryanum* the penetration of the cell walls of all parts of the potato tuber was apparently largely dependent on mechanical puncturing by the hyphæ, only tubers with mechanically weak cell walls being susceptible to decay by the fungus. The extreme susceptibility to *P. debaryanum* and *Corticium vagum* of soft, thin-walled tissues and the resistance of older stems and root parts would fit in well with such a theory as to the method of wall penetration, as in the older tissues the thicker cell walls would obviously be a serious bar to the extension of a fungus dependent partly or entirely on mechanical puncturing for its progress from cell to cell. Hartig (61, p. 147–150) shows a fungus which he does not name, but which is evidently a species of Fusarium, dissolving the young uncuticularized epidermis of pine seedlings; but he states that it can not so dissolve older epidermis. The increased protective value of the epidermis of older plants can only in part explain the immunity most of them develop against serious attack by damping-off organisms, as lesions already started or which may later develop from the infection of young roots are unable to extend into the older parts of the plants.

It may be mentioned here that the writer in a very preliminary test found strains of *Corticium vagum* and *Fusarium moniliforme* Sheldon which had been proved able to cause damping-off of pines also apparently able to destroy filter paper in inorganic salt solution, while *Pythium debaryanum* seemed not so able. Ruhland (116), on the other hand, found the strain of the "vermehrungspilz" (*Corticium vagum*) which he tested to be very weak in cellulose-destroying ability as compared with *Botrytis cinerea*.

DAMPING-OFF OF CONIFERS.

HISTORICAL.

While the losses from damping-off in seed beds of dicotyledonous tree species are occasionally serious and in the case of beech in Europe have required considerable study, they have been so far overshadowed in this country by the losses in coniferous seed beds that practically all the attention thus far, both as to etiology and measures of prevention, has been devoted to the disease in conifers.

The literature on the damping-off of conifers is considerable. A large part of it, because of the extensive early development of plant pathology and forest planting in Germany, has been written by Germans. A large portion of the German articles on it was either by foresters or by botanists in the day when most pathological work was of the reconnaissance type. Therefore, while the work of one of the best known of the parasites on coniferous seedlings was noticed in Europe as early as the eighteenth century (21, p. 252–253) most of the European data available are observational. The only fungi which were at all definitely connected with the disease on conifers seem to have been Fusarium (*Fusoma* spp.) and *Phytophthora fagi* (*P. omnivora* De Bary in part). The damping-off Rhizoctonia was described in Germany in 1858 and *Pythium debaryanum* in 1874; the fact that neither of these, important in coniferous seed beds in both the eastern and western United States, has ever been reported from conifers in Europe is perhaps the best evidence of the relatively small amount of actual investigation carried on there on this disease in the nurseries. A number of references to the damping-off of conifers in the English horticultural and botanical literature yield even less definite information as to the causal fungi than do the German articles.

With the awakening of interest in reforestation in the United States between 15 and 20 years ago and the first efforts to grow pines in quantity for forestry purposes, attempts were made to determine the cause of the disease in this country and to develop direct-control methods. Duggar and Stewart (32) made what appears to be the first report of Rhizoctonia in connection with the damping-off of conifers. Spaulding (136, 137), in work begun in 1905, contributed much to our knowledge of the etiology of the damping-off of pine in this country, especially in relation to Fusarium, and originated the sulphuric-acid method of control. The writer in 1910 reported preliminary inoculations on conifers with both Rhizoctonia and *Pythium debaryanum* (62). The work of Gifford (46) and Hofmann (77) added to the information on the causal relation of *Fusarium* spp. and *P. debaryanum*, respectively. Hartley, Merrill, and Rhoads (68) have recently established the parasitism of a number of strains of the *Corticium vagum* type of Rhizoctonia on pine seedlings under inoculation conditions, have confirmed Spaulding's conclusions as to the parasitism of *Fusarium moniliforme* Sheldon, and have given preliminary data on other fungi. They consider *P. debaryanum* and *C. vagum* more important in pine seed beds than any single Fusarium species. Hartley and Hahn (69) have announced successful inoculations on pines with *P. debaryanum* and *Rheosporangium aphanidermatus* Edson, with less satisfactory evidence of the parasitism of *Phytophthora* sp. and a fungus tentatively referred to *Pythium artotrogus.* Hartley and Pierce (67) report the finding of *P. debaryanum* in *Tsuga mertensiana* and *Pseudotsuga taxifolia* as well as in the pines. In damped-off pine seedlings they find *P. debaryanum* more commonly than *C. vagum*, especially in beds which have received disinfectant treatments. Other considerations, however, keep them from concluding that the former is necessarily the more important of the two. Both of these latter papers and all of the reports of Pythium with the exception of Hofmann's are brief notes, presenting no evidence in support of the statements made.

DESCRIPTION.

The symptoms of damping-off in conifers have already been described in some detail (68). In the paper cited, injury due to excessive heat of the surface soil and injury caused by high wind, both of which may easily be confused with damping-off, are described and accompanied by colored illustrations both of different types of damping-off and of these nonparasitic troubles. The detailed descriptions will not be repeated here. A brief summary of the different types of disease recognized as included in damping-off follows:

(1) Germination loss: The radicles are killed very soon after the seeds sprout and before the seedlings can appear above ground. This is an important type, which can be caused probably by any of the organisms commonly capable of causing the better known types of trouble (61, 63, 68, 137).

(2) Normal damping-off (figs. 3, 4, and 5): The seedlings are killed by fungi invading either the root or hypocotyl after the seedling has appeared above the soil and while the stem is still dependent largely on the turgor of its cortical tissues for support. In sandy soils root infection is more common than hypocotyl infection, though the latter is the type most emphasized in the early horticultural descriptions. Büttner (26) some time ago recognized the frequence of

FIG. 3.—Normal type of damping-off of *Pinus ponderosa*. At the left is a damped-off seedling or root sprout of the southwestern ragweed (*Ambrosia psilostachya*). (Photographed by S. C. Bruner.)

root infections. Damping-off in beds out of doors is primarily in most cases a root rot, either of this type or of the types preceding and following.

(3) Late damping-off includes cases of the root-rot type occurring only after the seedling stems have started to become woody and the cortex has begun to shrivel. The damping-off parasites, or at least part of them, continue to kill seedlings by rotting their roots for some time after the stems become too woody to be decayed. The seedlings affected do not fall over till a considerable time after death. For convenience, all cases of this sort up to the purely arbitrary age of two months are classed as damping-off. However, in weather permitting of average speed of development the seedlings are usually able to resist attack before they reach this age. Seedlings at the marginal age between susceptibility and nonsusceptibility to killing infections are found often with the younger parts of their roots killed, but with the older portions apparently able to resist invasion by the fungus, recovery taking place by laterals. Dr. R. D. Rands and the writer in 1911 established the ability of seedlings from 43-day-old beds of *Pinus sylvestris*, *P. banksiana*, *P. nigra austriaca*, and *P. nigra poiretiana* to survive such infections, even when more than half of the root system has been destroyed, by transplanting such root-sick seedlings and

observing their continued growth (fig. 6). An article recently found (25) shows that Büttner had earlier made the same sort of demonstration of recovery of root-sick conifers. Observations on olive seedlings in 1916 showed cases of partially rotted roots which were recovering by sending out lateral root branches.

(4) Top damping: The cotyledons or upper part of the stem are invaded by the parasite, sometimes before the seedling breaks through the soil. The infection may or may not be fatal. A special case of this type, probably caused by a different parasite from those most commonly active, is that which in a publication above referred to was described and figured as "black-top" (68). It is

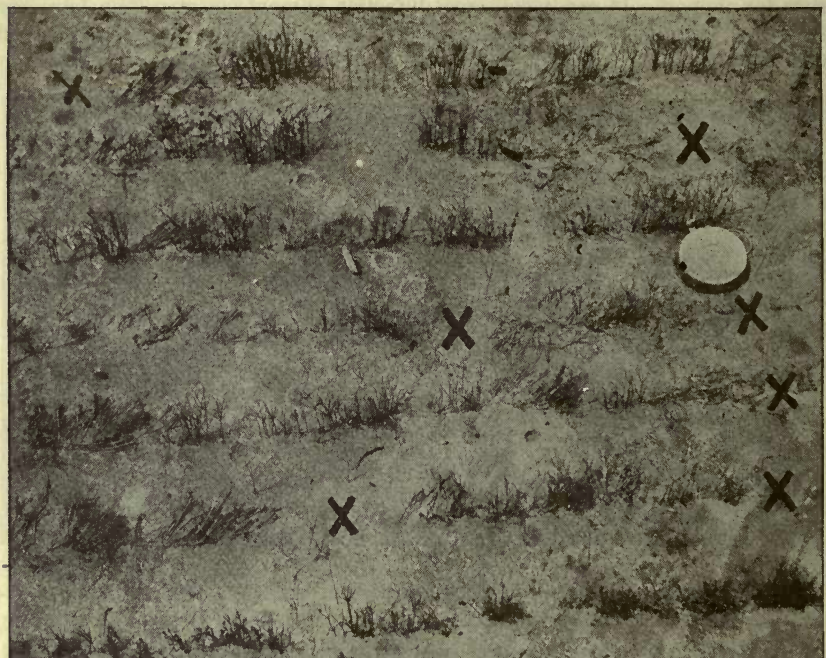


FIG. 4.—The beginning of an epidemic in drill-sown *Pinus banksiana*. Black crosses (X) indicate disease foci where the germinating seed were apparently killed and from which the disease is now spreading to adjacent seedlings. (Photographed by Dr. J. V. Hofmann.)

distinguished from ordinary top damping by the very dark color of the invaded tissues and its apparent dependence on some unusual set of climatic factors for its progress in the seedling after infection.

The killing of dormant seed by fungi is a matter of some practical interest in seed beds, and possibly still more so in forests, as it may help to explain the failure of certain conifers to reproduce except on mineral or certain other special soil types (68). With sugar beets *Pythium debaryanum* (100) is said to attack dormant seed as well as seeds which have sprouted. It is to be presumed that with conifers some of the damping-off fungi will be found to attack dormant as well as sprouting seed. This matter is now under investigation.

Something is already known about the seed fungi of herbaceous plants (76, 91), broad-leaved trees (79, 92), and juniper (95).

RELATIVE IMPORTANCE OF THE DIFFERENT TYPES.

Of the types of damping-off described in the foregoing pages the first two are ordinarily the most important. Late damping-off is rarely as serious as the normal type of damping-off. Top damping is only of importance in cases of excessive and unusual atmospheric moisture, so far as the writer's experience indicates. In the Middle West it has proved relatively insignificant. The three types which

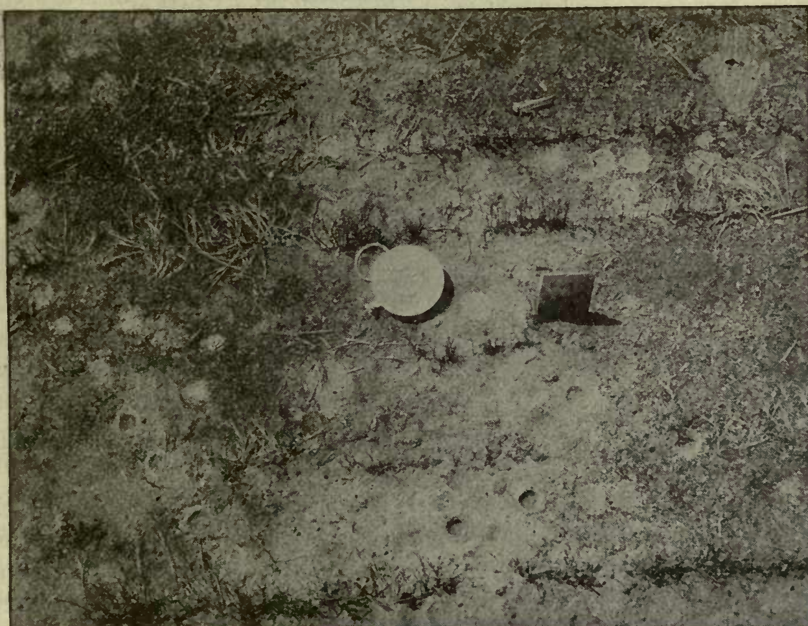


FIG. 5.—Nearly complete destruction of the seedlings of *Pinus banksiana* at an unusually early age, at Garden City, Kans. (Photographed by Dr. J. V. Hofmann.)

occur after the seedlings appear above the soil surface can, of course, be evaluated by frequent counts during the damping-off season. This has apparently not yet been done by anyone. However, in experiments on damping-off control by soil disinfection, data have been obtained on comparative emergence (number of seedlings appearing above the soil surface) in treated and untreated plats and on the total parasitic losses after the seedlings appear which permit a certain amount of analysis of the losses due to damping-off parasites. The data from five nurseries bearing on this point are presented in Table I.

TABLE I.—*Relative importance of losses by damping-off before and after conifer seedlings emerge from the soil.*

Nursery and species.	Series.	Basis.			Loss in control plats.			
		Disinfectant.	Number of plats.		Emerged (viable seeds).			Ratio of col. 6 to col. 7.
			Treated.	Controls.	Before.	After.	Total.	
1	2	3	4	5	6	7	8	9
Bessey (Nebraska sand hills):					*P. ct.*	*P. ct.*	*P. ct.*	
Pinus banksiana	Average of 9	Sulphuric acid	(a)	(b)	37.8	c27.2	65.0	c1.39
Pinus ponderosa	Average of 2	do	6	8	28.1	27.3	55.4	1.03
Pinus resinosa	Average of 3	do	4	7	29.4	54.1	83.5	.54
Garden City (southwestern Kansas):								
Pinus austriaca	Average of 2	Copper sulphate.	4	3	69.0	27.5	96.5	2.52
Pinus banksiana	do	Zinc chlorid	3	2	80.7	12.0	92.7	6.72
Pinus ponderosa	Average of 7	Copper sulphate.	17	29	15.3	30.9	46.2	.49
Cass Lake (northern Minnesota):								
Pinus resinosa	No. 1051	Formaldehyde	6	3	3.8	37.2	41.0	.10
	No. 1052	do	6	3	25.7	36.2	61.9	.71
	No. 1053	Zinc chlorid	4	4	5.7	26.2	31.9	.22
	No. 1054	do	4	3	7.4	43.6	5.1	.18
	Nos. 1057 and 1061.	Heat	4	2	4.9	16.9	21.8	.29
East Tawas (Michigan):								
Pinus resinosa	1073	Formaldehyde	6	3	5.9	45.3	51.2	.13
	1074	Sulphuric acid	2	7	58.2	18.0	76.2	3.25
Fort Bayard (New Mexico):								
Pinus ponderosa	Nos. 791 and 792.	Formaldehyde	7	8	12.6	36.1	48.7	.35
	Nos. 891 and 892.	Sulphuric acid	8	6	14.5	18.6	33.1	.78

[a] Area counted, 122 square feet. [b] Area counted, 78 square feet.
[c] In *Pinus banksiana* at the Bessey Nursery, the loss after emergence is slightly low and the ratio slightly high, because of the closing of counts on a few of the series before damping-off was entirely over.

The procedure was to average the number of seedlings which emerged in the control plats in each series and subtract this number from the average number emerging (that is, appearing above the soil surface) in the treated plats in the same series. The treated plats chosen were the ones which allowed the averaging of the greatest number of plats treated with the same disinfectant. Only those plats were taken in which there was no evidence of injury to the seed or seedlings by the disinfectant and in which the amount of normal damping-off during the first few days after emergence was so slight as to indicate satisfactory initial control of the parasites by the treatment. In such plats it was assumed that the germination loss was unimportant, and the average number of seedlings appearing on them was taken as representing the number of viable seeds per plat. The difference between this emergence figure and the average emergence in the controls was taken as indicating the extent of parasitic loss before the seedlings appeared, including any destruction of dormant seed by parasites which may have occurred as well as the killing of germinating seed. Both this figure and the number of seedlings which succumbed to damping-off after emergence were reduced to a percentage based on the indicated number of viable seeds, and they are directly compared in columns 6 and 7 of Table I. At three of the nurseries the data of the same species of pine and with the same treatment were averaged.

The data in Table I do not indicate any regularity either in the extent of loss before emergence, the loss after emergence, or in the ratio between these two values. For obvious reasons, no regularity is to be expected in any of these items. The table is of some interest, however, in confirming the evidence of the inoculation experiments, of observation of sprouting seed dug up in the beds, and of the partial or complete failure of emergence at the centers of large damping-off foci (figs. 4, 7, and 8) that the work of parasites before the seedlings appear may in some cases be of considerable importance. It is obviously impossible to make any general quantitative statement of the seriousness of such loss, in view of the variation in its extent at different times and places and of the inaccuracy of any computations based on the relative emergence of hosts as irregular in their germination as the conifers are known to be. The case is complicated in addition by the fact that, despite careful avoidance of treated plats known to have suffered chemical injury, it is probable that a few seedlings were killed before emergence by the disinfectants used in some of the

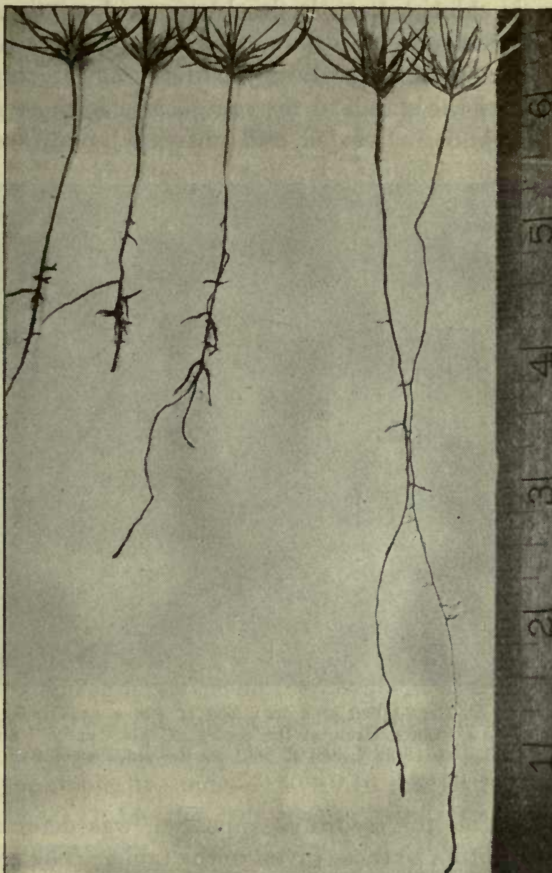


FIG. 6.—Root sickness in *Pinus nigra poiretiana*. The two seedlings at the right are healthy. The three at the left have had their taproots decayed to within $1\frac{1}{2}$ inches of the soil surface. All are putting out lateral roots from the lowermost sound point. Similarly injured seedlings when transplanted lived and made satisfactory growth.

cases. It may furthermore be that in other cases the disinfectant had a stimulating effect, resulting in better germination in the treated plats, entirely aside from that resulting from parasite control. The number of disinfectant methods which concurred in giving apparent increases in germination, however, makes it seem reasonably certain that no great part of the increase was due to this stimulation.

In addition to the different disinfectants shown in the table, mercuric chlorid, heat, hydrochloric acid, nitric acid, and ammonia all apparently resulted in approximately the same increases of germination in tests at the Bessey Nursery as the sulphuric acid which was used as the standard for comparison in most of the series. Relative emergence in treated and untreated plats, as well as damping-off

FIG. 7.—A clean-killed area in a bed of *Pinus ponderosa,* caused by *Corticium vagum.* Inside a 12-inch circle at the center of this "patch" no seedlings appeared. It will be noted that the weeds as well as the pines have been killed with the exception of *Salsola tragus.*

loss after the seedlings appeared, was determined at two nurseries in addition to those given in the table. The results at these nurseries in general confirmed those at the five nurseries covered by the table in showing lower emergence in the controls. Although it is impossible to draw positive conclusions, some idea of the seriousness of losses before the appearance of the seedlings above ground can be obtained by studying the data in Table I. The fact that such losses appear considerable, sometimes exceeding the losses from the damping-off that occurs after emergence, is believed to explain the common failure to secure satisfactory results from control measures taken after the seedlings have come up and the disease has become noticeable. It is somewhat interesting to note that the data in the table tend to confirm field observations that, as compared with other species, *Pinus resinosa* is more susceptible to the later forms of damping-off than to germination loss.

Further indication that the killing of germinating seed before emergence may be important enough to help explain cases of poor germination is obtained by an entirely different method, as follows: At the Wind River Experiment Station of the United States Forest Service counts of the seedlings emerging and of those which later died were made on a number of untreated plats by forest officers, who kindly permitted the writer to use the data obtained. The counts were made separately on 10 plats each of noble fir (*Abies nobilis*) and silver fir (*Abies concolor*). The plats of each species had been sown with equal quantities of seed. It appeared on inspection of the figures that the plats which showed the poorest emer-

FIG. 8.—The area shown in figure 7 after the bed had been weeded and damping-off had practically ceased. (Photographed by S. C. Bruner.)

gence were also the ones which suffered the most subsequent loss. The coefficient of correlation between the number of seedlings emerging and the percentage of subsequent loss in the same plats was found to be -0.49 ± 0.16 for the noble fir, and -0.50 ± 0.16 for the silver fir, an average of -0.49 ± 0.11 for the two species, confirming the conclusion drawn from inspection of the figures. In other words, poor emergence and heavy subsequent loss were in general associated. The simplest explanation of this association appears to be to suppose that both poor emergence and subsequent loss were largely due to the same cause, namely, the damping-off parasites. Another possible explanation of the correlation would be to neglect parasites as important causes of the poor emergence in certain plats and to suppose that the higher subsequent loss in such plats was due to heat injury, the less dense stands affording less shade to the bases of the seedlings composing it. As damping-off is in general so much more important than heat injury as a cause of death after emergence and the difference in the degrees of shade between the plats with the denser and the plats with the thinner stands must have been very slight, this latter explanation has not much to support it. The data are believed to constitute further evidence of the importance of parasites in decreasing the percentage of emergence in coniferous seed beds. That the effect of parasites on emergence should have been large enough in this case to make itself apparent on the face of the figures, despite the variations due to other sources, is especially interesting in view of the fact that the losses after emergence in these plats were not high.

ECONOMIC IMPORTANCE OF DAMPING-OFF.

The importance of damping-off in coniferous nurseries in Europe is indicated by frequent reference to the disease in the literature. Büttner (25, 26) states that whole beds are frequently destroyed by it. Baudisch (9) speaks of the death of entire stands in many nurseries as the result of damping-off. In the United States Spaulding (137) considers damping-off a serious obstacle in forestation operations. Clinton (28, p. 348–349) reports serious damage to conifers in New England nurseries. The writer has found the disease especially prevalent in nurseries in Nebraska and Kansas, a somewhat unexpected situation in view of the relatively dry conditions prevailing there. A correspondent has reported heavy loss in seed beds in Texas.

The economic importance of the disease in conifers is due in part to the rather heavy average losses experienced at many nurseries and in part to the irregular character of the losses. In one season losses may be negligible, while the next season the beds of certain species may be practically wiped out. Even without this element of uncertainty the losses experienced are expensive, because of the high cost of coniferous seed. The seed of some species costs from $3 to $5 a pound and seldom shows a germination of more than 60 per cent under nursery conditions. A loss of half of this 60 per cent from parasites, both before and after the seedlings break through the soil, is therefore a matter which deserves attention. The figures in column 8 of Table I, obtained by adding together those in columns 6 and 7, show that the loss is frequently higher than this. At the nurseries at which control experiments have been conducted, the percentage of the seedlings in untreated beds which have been found by actual count damped-off after emergence is frequently more than 50 per cent, in addition to the considerable but less accurately determinable loss indicated by the foregoing data as being caused by the parasites before the seedlings appear.

It has been suggested by foresters and others that the net economic damage from damping-off is not as great as is indicated by the loss of seed and seedlings which it may cause. The argument is ad-

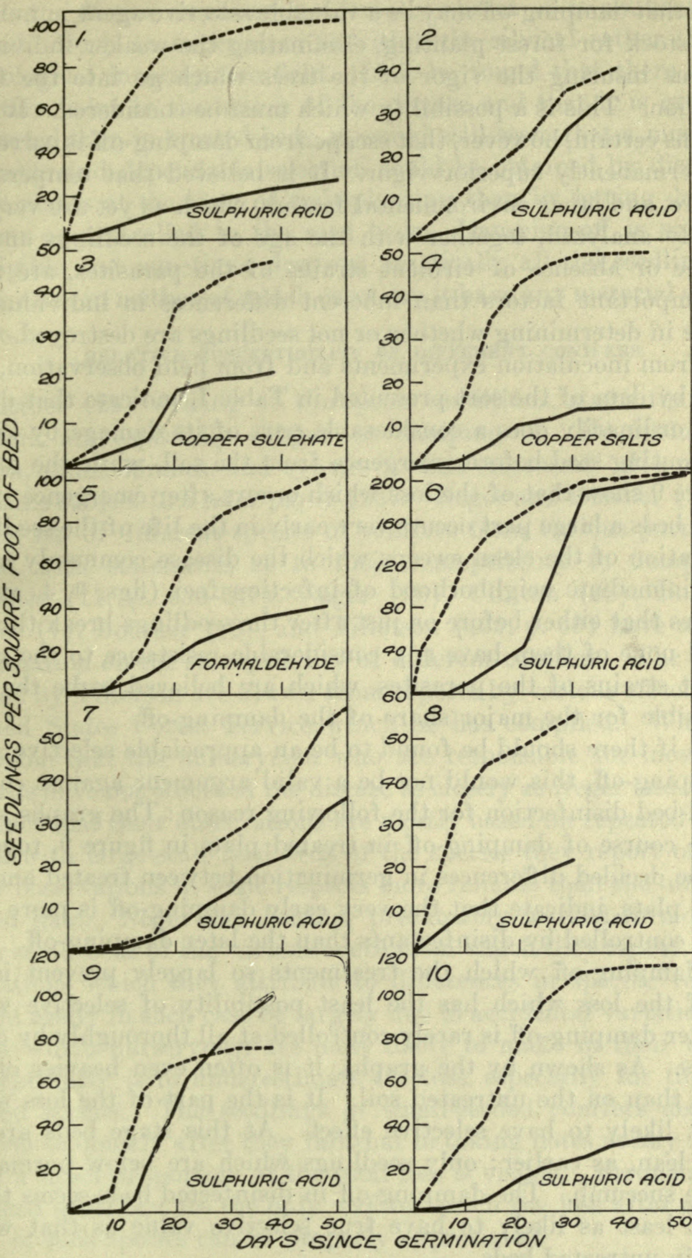


FIG. 9.—Diagram showing the progress of damping-off in treated plats (solid line) as compared with untreated plats (broken line). Graphs 1 to 4 represent *Pinus ponderosa;* graphs 5 to 8, *P. resinosa;* graph 9, *P. banksiana;* and graph 10, plats each of which was half *P. nigra poiretiana* and half *P. sylvestris.* Nurseries in Kansas, Nebraska, Minnesota, and Michigan are represented. The relatively high total number damped-off in the treated plats shown in two of the graphs is due to the fact that a large proportion of the seedlings in the untreated plats had been killed before they appeared above the soil surface. In both the cases in which the absolute number of seedlings killed was as great in the treated plats as in the controls, the percentage of the seedlings killed was nevertheless lower and the survival more than twice as good as in the controls.

vanced that damping-off may be a valuable selective agent in nursery-grown stock for forest planting, eliminating the weaker individuals and thus insuring the vigor of the trees which go into the forest plantation. This is a possibility which must be considered. It is by no means certain, however, that escape from damping-off is correlated with permanently superior vigor. It is believed that temperature, moisture, and other environmental factors, which as yet are very imperfectly analyzed, together with the age of the seedlings and the presence or absence of virulent strains of the parasites, are much more important factors than inherent differences in individual resistance in determining whether or not seedlings are destroyed. Evidence from inoculation experiments and from field observation, supported by data of the sort presented in Table I, indicate that damping-off ordinarily does a considerable part of its damage by killing the sprouting seed before emergence from the soil, while the graphs in figure 9 show that of the loss which occurs after emergence in untreated beds a large part occurs very early in the life of the seedlings. Observation of the clean sweeps which the disease commonly makes in the immediate neighborhood of infection foci (figs. 3, 4, and 5) indicates that either before or just after the seedlings break through the soil none of them have any considerable resistance to the really virulent strains of the parasites, which are believed to be the ones responsible for the major share of the damping-off.

Even if there should be found to be an appreciable selective value in damping-off, this would not be a valid argument against control by seed-bed disinfection for the following reason: The graphs showing the course of damping-off in treated plats in figure 9, together with the decided differences in germination between treated and untreated plats, indicate that the very early damping-off is more completely controlled by disinfectants than the later damping-off. This early damping-off which the treatments so largely prevent is the part of the loss which has the least possibility of selective value. The later damping-off is rarely controlled at all thoroughly by disinfectants. As shown by the graphs, it is often even heavier on the treated than on the untreated soil. It is the part of the loss which is most likely to have selective effect. At this stage beds are not taken clean, as earlier; only seedlings which are below normal resistance succumb. The damping-off in disinfected beds seems therefore at least as likely to have true selective value as that which occurs in untreated beds.

The only way in which the effect of damping-off as a selective agent can be positively determined will be to compare through several subsequent years the growth rate, or survival after transplanting, of trees from beds which suffer seriously from damping-off with the growth of trees from the same lot of seed in seed beds in which the disease is either accidentally absent or is artifically controlled. Such an experiment is within the silvical rather than the pathological investigative field. If it be found that there is some selective value in the action of the disease and that it is greater in untreated than in treated beds, it would still seem that a much more desirable and dependable selection could be obtained by discarding weak plants at the time of transplanting than by letting damping-off run uncontrolled in the seed beds. Damping-off is sometimes negligible and sometimes destroys practically all the seedlings in a given area, in neither of which cases can it have any material selective value.

RELATIVE SUSCEPTIBILITY OF DIFFERENT CONIFERS.

Büttner (25) writing of European conditions, states that exotic conifers are especially subject to damping-off. He includes fir, spruce, pines, larches, and cypress in this statement. He mentions the same subject in a later paper (26). Neger and Büttner (94) give a long list of different species of conifers from various parts of the world with statements as to their susceptibility to damping-off. Beissner (11, p. 656–657), Neger (93), Clinton (28), Bates and Pierce (7), Boerker (13), and Tillotson (139, p. 69) have all given information on the susceptibility of different conifers. The data reported by Tillotson are drawn from reports by various officers of the United States Forest Service which he has compiled. While it is probable that the nurserymen who are responsible for most of his records have not observed the disease as closely as Neger and Büttner, the fact that their observations are mostly based on repeated seasons' work with large-scale seed beds of the species they report on makes their observations in some respects more reliable than the other published data. Neger and Büttner presumably worked in most cases with small beds of the various conifers on which they report, and the variations which they attribute to differences in specific resistance might easily in such case be largely due to accidental variation. The error which nurserymen are most likely to make in their notes on susceptibility is to underestimate the loss, especially for the small-seeded species. The seedlings of small-seeded conifers decay and shrivel so quickly after they fall that in taking notes at any one time only a small proportion of the total loss is visible. Frequent counts of dead seedlings are the only way by which the loss after germination in such species can be properly appreciated.

The data given by the authors mentioned in the foregoing paragraph, together with unpublished data obtained by personal observation or from commercial and other nurserymen in the United States, are summarized in Table II, the source of each report being shown by letters signifying the authority. The unpublished data on two nurseries in Illinois and Minnesota were obtained from the nurserymen by Mr. R. G. Pierce and are indicated by the initial "P." Information obtained directly from the nurserymen by the writer is indicated by "N." For nurseries where the statements are based on the writer's personal observation rather than on the authority of the nurserymen, his own initial ("H") is given. Most of the writer's own estimates of relative susceptibility are based on a comparison of detailed counts of the damped-off seedlings in a large number of untreated plats at different times, as well as on observation. The nurseries on which Tillotson reported were all west of the Missouri River, most of them being in the mountain region. The reports indicated by "H" and "N" were mostly from nurseries east of the Rocky Mountains. In cases in which the data permit it, the species are classified as most susceptible, intermediate, least susceptible, or immune. In a number of cases, however, it is only possible to classify them as "more" or "less" susceptible.

TABLE II.—*Relative susceptibility to damping-off of different conifer species.*

[Figures in parentheses in this table indicate the number of nurseries from which the susceptibility noted has been reported by the observer to whom the preceding letter refers.]

Host species.[a]	Reports of relative susceptibility.[b]					
	Not susceptible.	Least susceptible.	Less than average.	Intermediate.	More susceptible than the average.	Most susceptible.
Pinaceæ (Abietoideæ):						
Abies spp		(c)				
Abies balsamea		Nb				
Abies cephalonica				Nb		
Abies concolor						Bu, Nb.
Abies nobilis			T			Nb.
Abies nordmanniana				Nb		
Abies picea (A. pectinata)				Nb		
Abies sacchalinensis (?)				Nb		
Abies sibirica		Nb				
Abies veitchii						Nb.
Cedrus deodara			T			
Larix europæa				Nb	N (2)	
Larix leptolepis						Nb.
Larix occidentalis			T		T	
Picea ajanensis			Ne	Nb		
Picea canadensis		Nb		P	N	
Picea engelmanni			T (2)		H, N, Ne, T.	Nb.
Picea excelsa	P	Nb	H, Bu		Ne, N	
Picea omorika			Ne	Nb		
Picea orientalis			Ne	Nb		
Picea pungens			N (2)	H, P	Ne	N (2), Nb.
Picea sitchensis					Ne	Nb.
Pinus aristata		Nb				
Pinus attenuata					N	
Pinus banksiana		Nb	N	P	B, P, H (2), T.	B., H.
Pinus contorta	T	Nb	T			
Pinus edulis	T					

[a] Host names for American species follow the usage in the publications and a later verbal communication of Mr. George B. Sudworth, of the United States Forest Service. For exotic species the Standard Cyclopedia of Horticulture, New York, 1916, edited by L. H. Bailey, is taken as the standard. The classification follows Saxton (118).

[b] Symbols signifying the authority for the report: B=Boerker (13), Bu=Büttner (25, 26), Bp=Bates and Pierce (7), C=Clinton (28), H=Writer's estimate, N=Nurserymen's estimate (obtained by the writer), Nb=Neger and Büttner (94), Ne=Neger (93), P=Nurserymen's estimate (obtained by Pierce), T=Forest officers' estimate (compiled by Tillotson, 139).

[c] Susceptibility to *Phytophthora fagi*.

TABLE II.—*Relative susceptibility to damping-off of different conifer species*—Continued.

Host species.	Reports of relative susceptibility.					
	Not susceptible.	Least susceptible.	Less than average.	Intermediate.	More susceptible than the average.	Most susceptible.
Pinaceæ (Abietoideæ)—Continued.						
Pinus excelsa		Nb				
Pinus flexilis		N				
Pinus jeffreyi			T		T (2)	
Pinus lambertiana					T	
Pinus montana mughus				P		
Pinus monticola	T		T		T	
Pinus nigra austriaca (Austrian pine)		Nb	N, T (3)		Bp, N, T	
Pinus nigra poiretiana (Corsican pine)	Bp			H		
Pinus palustris				B		
Pinus peuce		Nb				
Pinus ponderosa (type not specified)	T (3)	P	Bp, N (4), T (6).	Nb	T (4)	
Pinus ponderosa (Eastern Rocky Mountain type)			H (4)		B	
Pinus ponderosa (Pacific coast type)			B			
Pinus resinosa			N (3)		Bp, H, T	B, H.
Pinus rigida			P		N	
Pinus strobus	P		B, H, N	N	C, N, T	
Pinus sylvestris			T (2)	H, P	Bp, T (3)	N.
Pinus taeda		B				
Pinus thunbergii		Nb				
Pseudotsuga taxifolia (type not specified)			N (3) T (3)	H	N, T (5)	
Pseudotsuga taxifolia (Colorado type)		Nb			B	
Pseudotsuga taxifolia (Northwestern type)		B		Nb		
Tsuga canadensis				Nb, P	Bu	
Number of reports	9	17	51	23	48	15
Percentage of total	6	10	31	14	29	9
Sciadopitoideæ:						
Sciadopitys verticillata						Nb.
Cupressaceæ (Cupressoideæ):						
Chamaecyparis lawsoniana		Nb	T		Bu	
Chamaecyparis pisifera		Nb				
Cryptomeria japonica				Nb		
Cupressus spp		Nb				
Cupressus arizonica	N					
Juniperus communis	Nb			P		
Juniperus monosperma	N					
Juniperus pachyphloea	T					
Juniperus virginiana	H, P	Nb				
Libocedrus decurrens	T	Nb	T			
Taxodium distichum		Nb				
Thuja occidentalis	P	Nb				
Thuja orientalis	P			Nb		
Thuja plicata				Nb		
Number of reports	9	7	2	4	1	0
Percentage of total	39	30	9	17	4	0
Sequoideæ:						
Sequoia spp					B	
Sequoia washingtoniana					T	
Taxaceæ:						
Taxus cuspidata	P					

The fact most evident in Table II is the extreme variation between reports, not only on closely related species but even on the same species. While it is, of course, possible that the obvious lack of a definite basis and method of comparison in most of the reports is responsible for most of this variation, it seems to the writer more probable that different species do actually vary in their relative susceptibility to damping-off in different localities. In the first place, the conditions which might increase resistance of one host might very easily decrease its resistance for a host with different environmental requirements. To illustrate by an extreme example, the piñon (*Pinus edulis*) of the arid or semiarid region might remain resistant in soils in which *Picea engelmanni* of the high mountain-stream bottoms or *Picea mariana* of the northern swamps might be low in vigor and easily attacked. In the second place, it is to be expected that species with a certain order of relative susceptibility to the parasites which predominate at one nursery may exhibit a very different order of susceptibility to the different combination of parasites which might be prevalent in another locality.

The only individual species on which there are a sufficient number of reports and a sufficient agreement between the reports are the two common western spruces, *Picea pungens* and *P. engelmanni*, which (at least as compared with *Picea excelsa*) seem rather susceptible, and *Pinus ponderosa*, which (as compared with most of the other species of the Abietoideæ) is to be regarded as generally more resistant than the average. Within each of the larger genera of this group it seems evident that susceptibility is extremely varied and that no statement as to the relative susceptibility of the genera themselves can therefore be made. The only group generalization that is perhaps permissible is derived from the consideration of the Cupressoideæ. In this group, out of 23 reports, 16 are in the "not susceptible" or "least susceptible" columns and only one indicates more than intermediate susceptibility. Of 163 reports pertaining to the Abietoideæ, only 26 place them in the "not susceptible" or "least susceptible" columns and 63 in the classes of more than intermediate susceptibility. The general feeling among nurserymen seems to be that serious damping-off need not be feared among the cedars and their relatives. The data at hand tend to justify this confidence.

CONTROL OF DAMPING-OFF.

Early efforts to prevent damping-off were chiefly directed to the avoidance of excessive moisture in either the air or soil. A means to this end, which has been observed more or less by nurserymen for many years, both in the United States and elsewhere, is the application of small quantities of dry sand to the seed beds after the disease becomes noticeable (18, p. 166; 83). This is sometimes applied hot (101, p. 43–44; 145), though even this procedure does not result in very great advantage. Surfacing with hot sand can not always be counted on to give any measurable advantage over untreated beds (67, p. 3). The use of sand (25) or sterile subsoil (101) instead of ordinary soil in covering seed at the time of sowing has been advised. Johnson (82) did not secure satisfactory results with sand in tobacco beds. Making the upper part of the bed to a depth of several inches of recently dug subsoil appeared effective in a single test by Spaulding (137) and at four nurseries by cooperators of the writer in later tests, the results of which will be published elsewhere. The procedure is unfortunately rather expensive in large-scale work and under some conditions at least undesirable because of the poor subsequent growth on such soil. Excessive vegetable matter (45), imperfectly rotted manure (67), or green manures recently plowed under (43) have all been advised against as likely to favor the disease. The experience reported with conifers (67, 139) indicates that damping-off can be to a certain extent decreased by broadcast sowing as compared with sowing in drills. The usual recommendation of thin sowing to avoid the seed-bed disease of other plants has also been made for conifers (67). Transplanting healthy seedlings from infected beds into new soil is recommended as a means of saving them from attack (11, 145). The writer's tests of transplanting at a Nebraska nursery gave no promise of economic value as a control method, although he is informed that it was successfully employed in a nursery in New Mexico. The time of sowing appears to have a relation to the amount of disease at some nurseries, but conditions in this regard evidently differ in different localities, so that the best time to sow from the standpoint of avoiding damping-off must be determined separately by repeated tests at each nursery. For example, observations both by the nurserymen and the writer during several seasons at the Bessey Nursery, in Nebraska, indicate that fall sowing is an excellent means of decreasing loss from damping-off in at least one pine species, and Retan (110) reports the same thing for a nursery in Pennsylvania, while at two Kansas nurseries and at nurseries mentioned by Tillotson (139) fall-sown beds suffer more than those sown in the spring.

Treatment of the seed with mercuric chlorid (25) or with copper sulphate (122) has been recommended. While it has been demonstrated (38) that a proper heat treatment of the seed will greatly decrease the damping-off in sugar-beet seedlings, this is explained by the fact that one of the most important parasites of the sugar beet is systemic and often present in the seed. There is no reason to believe that seed-carried infection is of any importance in coniferous seed beds. The only advantage that could reasonably be expected from a seed treatment of conifers would be that which would come from the prevention of seed decay in the soil before germination starts, and this protection could be expected to be effective only if a relatively insoluble disinfectant, such as Bordeaux mixture, was used.

Soil treatment is the most direct and probably the most profitable method of attack on the disease. It is especially easy, for tobacco seedlings (82) as well as for pines, to prevent by soil disinfection losses before the seedlings appear above the ground. Heat disinfection of seed beds has been frequently mentioned. Burning wood or litter on the surface of the beds before sowing, said by Gilbert (47, p. 36) to be a common procedure in preparing tobacco seed beds both in Italy and in parts of this country, has been recommended for coniferous seed beds by Büttner (25). The disadvantageous results sometimes noticed following the application of wood ashes to pine seed beds may prove an objection to this type of treatment in some of the nurseries. At a Nebraska nursery (67) moist heat proved only partly satisfactory, unavoidable reinfection having serious results. Steam disinfection, using the inverted-pan method commonly advocated for tobacco seedlings (10, 47, 81), has been reported by Scott (123) as successful at a nursery in Kansas. Gifford (46) found steaming with the inverted pan only partly satisfactory. It is not believed that it is likely to pay to install the necessary apparatus for steam disinfection at nurseries in nonagricultural districts where steam tractors are not available for temporary use. The hot-water soil treatment as used by Byars and Gilbert (27) is probably worth a trial at any nursery where damping-off is serious and fuel cheap. It may be that in some localities where steam or hot-water treatment of the soil is not sufficiently effective, its efficiency can be increased by reinoculating the soil immediately after treatment with saprophytic molds and bacteria to provide maximum competition for parasites which come in from the outside. Tests of this procedure will be described later in the present bulletin. The value of charcoal has been emphasized by Retan (109, 110).

Chemical disinfection of the soil has also been employed. Sulphur has long been in use as a soil treatment against the damping-off of various plants (45, 111) in addition to its use in combating potato scab and onion smut. It was tested on conifers by Spaulding (136, 137) in the form of light surface applications to the beds after germination, but without decisive result. In later cooperative tests powdered sulphur raked into the soil before the sowing of the seed failed to indicate any large measure of value. Very finely divided forms of sulphur in various amounts and times of application are probably worth some further test.

Möller (90) and Sherbakoff (128) have reported the successful use of copper sulphate in combating attacks of Corticium on dicotyledons. In Johnson's experiments on tobacco seedlings (82, table 3) copper salts and Bordeaux mixture were the only chemicals for which any value was indicated. Sherbakoff apparently used copper sulphate and other strong disinfectants chiefly to stop the extension of vigorously spreading damping-off foci by local treatment rather than as a general treatment for use over the beds. Such treatment would presumably kill all seedlings on the area treated, but would, of course, be of considerable value in stopping at the outset such mycelia as those which caused the damped-off area in figure 7. The procedure would be of practical value only in cases in which damping-off was chiefly limited to a few large patches of this sort, a rather rare condition in conifers.

Copper sulphate solutions have been used on pine seed beds at the time of sowing with considerable success at some nurseries (65, 67). Except in a nursery in which the soil contained carbonates, it has proved rather difficult to prevent injury to the pines. The trial of some such combination of copper sulphate and lime as was used by Spaulding (136) on the surface of pine beds before sowing, which apparently prevented the damping-off of lettuce in some unpublished pot experiments of Mr. J. F. Breazeale, is considered desirable. Treating seed beds with ordinary Bordeaux mixture has also been recommended. Horne (78) secured especially good results against *Corticium vagum* in tobacco seed beds by heavy applications of Bordeaux mixture, and Schramm (122) and Clinton (28) have obtained indications of its value as a spray in preventing the damping-off of conifers. It is probably worth further tests in various amounts of application. In tests conducted by the writer in 1912 and still unpublished, some advantage was indicated for Bordeaux mixture as a surface treatment after soil disinfection with acid. Zinc chlorid as a soil disinfectant has also been found valuable in a number of cases (65, 67), but it is more expensive and apparently less dependable than copper sulphate.

Formaldehyde and sulphuric acid have been tested more frequently than other disinfectants. The use of sulphuric acid on coniferous seed beds was originated by Spaulding (136). The first intensive experiments with this acid were reported by the writer (63). The first experiments with formaldehyde on conifers seem to have been in the early greenhouse tests of Spaulding (137), repeated in forest nurseries in 1907 by Jones (83) and Spaulding (136). Most of the experiments with these two substances have already been summarized (67). A report not mentioned in this summary is that of Schaaf (119, p. 88), who obtained favorable results with the acid. The great trouble with formaldehyde is its tendency to kill dormant seed. The length of time which must be allowed to elapse between treatment and sowing in order to avoid this killing varies with conditions. Formaldehyde is more expensive than acid and seems on the whole to have been less effective in disease control. Acid, on the other hand (applied just after the seed is sown, which is found to be the best time), on a few soils has caused injury to radicles, which it was at first thought could be prevented only by very frequent watering during the germination period; while in a few cases, when cold weather resulted in a long germination period, it has killed or inhibited the germination of some of the dormant seed. All injury can be prevented by treatment a few days before sowing, followed by the addition of lime just before sowing, but lime used in this way has apparently destroyed a considerable part of the value of the acid treatment against the disease. Further consideration of the data on which earlier papers (63, 67) were based indicates that the apparent need for frequent watering during the germination period, which was required at a few of the nurseries where the first tests of acid treatment were made, as well as practically all of the germination reduction, was due to the use of unnecessarily large applications of acid and that the trouble can be eliminated by determining by test the minimum quantity of acid which will be reasonably effective in each locality. If this can be done it should establish the acid treatment as the most profitable for general use of any of the methods of damping-off control which have so far been extensively tested.

In view of the various parasites which may cause damping-off at different times and places and which vary greatly both in their means of dissemination and in their physiological qualities, it is not believed that any single disinfectant will be found entirely satisfactory at all nurseries. It is also unfortunately true that no one strength of treatment can be recommended for all nurseries. The quantity of acid to be used at any specified nursery will have to be determined by test at that nursery. A single test, no matter how well conducted, is not sufficient to serve as a basis for conclusions. However, a number of small-scale tests, made at different times and in different parts of the seed-bed area, should determine the best treatment for any particular nursery with a reasonable degree of certainty and with very little work. If the plats are equal in size and receive equal quantities of seed, all the nurseryman needs to do to determine the value of the treatments is to count the number of living seedlings on the different plats at the end of the season. The decrease in the number of weeds as a result of the use of acid is itself sufficient at a number of nurseries to pay the entire cost of the treatment. Detailed methods of application have already been published (67). The differing proportions of acid between which the best treatment will ordinarily be found to lie are 2 and 7 c. c. (one-sixteenth and one-fourth of a fluid ounce) of the concentrated commercial acid per square foot of seed bed, applied just after the seed is sown and covered. It should be dissolved in 500 to 1,000 c. c. (1 to 2 pints) of water per square foot of bed before applying. The drier the soil before treatment, the more water should be used in dissolving the acid.

No treatment applied after germination begins can have the maximum value in controlling the disease, because the damping-off parasites frequently, if not usually, do part of their work before the seedlings appear above the soil. Furthermore, any treatment at all effective against the disease is almost certain to hurt the seedlings if applied after the seed starts to sprout.

Both the acid and copper-sulphate treatments which have been found useful in pine seed beds are of very doubtful value for most hosts other than conifers, as the angiosperms on which observations have so far been made are too easily injured by the disinfectants. The weeds in the nurseries have been injured or entirely kept from appearing by treatments which caused no injury to the pines.

CAUSAL FUNGI.

CORTICIUM VAGUM.

Occurrence and parasitism.—In a recent publication (68) *Corticium vagum* B. and C. (*C. vagum solani* Burt, *Hypochnus solani* Pril. et Del., the common damping-off Rhizoctonia) has been reported on a number of conifers. Inoculation, reisolation, and reinoculation on pine have established its parisitism on this host beyond a reasonable doubt, though in these inoculations, as in most, if not all, the work which has been done with the fungus on angiospermous hosts, the cultures employed have been from plantings of diseased tissue instead of from single spores. The inoculation experiments have confirmed the field observations indicating that this fungus is fully as able to cause loss by destroying germinating seed below the soil surface as to cause damping-off of the better known type after the seedlings appear above the soil surface.

An extensive list of angiosperms on which the fungus has been reported is given by Peltier (98). Cross-inoculations between the pines (68), on the one hand, and potato (40) and sugar beet (38) have shown the same strains to be parasitic on both conifers and angiosperms and established the physiological as well as the morphological identity of the fungus attacking pines with the common *Corticium vagum*. Now that Duggar (34) has offered strong, though not yet entirely conclusive, evidence of the identity of *C. vagum* with the European "vermehrungspilz" (the *Moniliopsis aderholdii* of Ruhland; 115) it is to be presumed that it is a cause of damping-off of conifers in Europe as well as in America, though no reports of it on conifers have been so far encountered in European literature. The Rhizoctonia reported by Somerville (132) on *Pinus sylvestris* and the *Rhizoctonia strobi* described by Scholz (121) as killing young *Pinus strobus* were both on trees more than 4 years old, so that they had no relation to damping-off. Furthermore, the first of these was apparently the old *Rhizoctonia violacea*, now known as *R. crocorum* (*R. medacaginis*), a fungus entirely distinct from *Corticium vagum*, probably belonging to an altogether different group of fungi and not known to cause damping-off of any host. *Rhizoctonia strobi* is not sufficiently described to allow determination of its identity.

Variations in virulence.—In the inoculations earlier reported on conifers, different strains of *Corticium vagum* were said to vary greatly in virulence (68). Further examination of the data on which this statement was based yields confirmatory evidence. Part of this evidence is shown graphically in figures 1, 2, and 10. The experiments on which these graphs were based involved at the time of seed sowing the addition to the soil of apparently pure cultures of *C. vagum.* Throughout each experiment the different units received

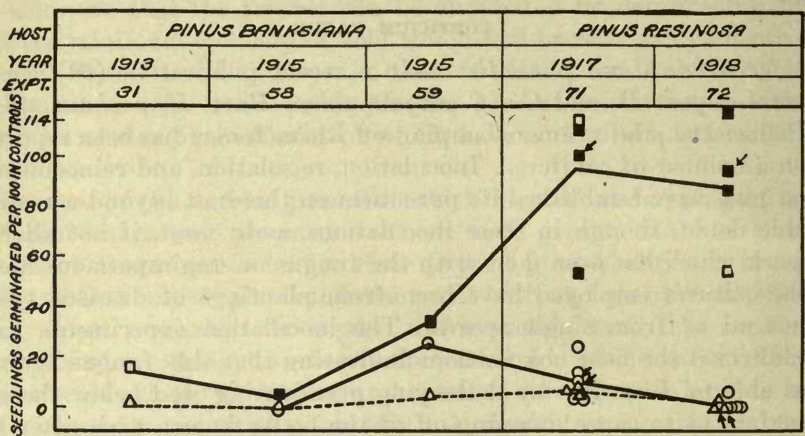


FIG. 10.—Diagram showing the relative activity of different strains of *Corticium vagum,* as indicated by the number of seedlings appearing in inoculated pots. Explanation of symbols: ○ =Strain 147, from spruce seedlings, Washington, D. C., 1910; ▽ =strain 213, from sugar beet seedlings, Washington, D. C., 1911; ■=strain 230, from *Elaeagnus* sp., Kansas, 1913; □ =strain 233, from the same lesion as strain 230. Strains reisolated from these, the results of which appear in experiments Nos. 71 and 72, are indicated by the same signs as the original strains used in the inoculations from which they were taken. The original strains in experiments Nos. 71 and 72 are indicated by arrows.

equal quantities of seed, and the culture substratum used in inoculating was the same for all strains. Experiments 36, 45, 47, 49, and 51 were conducted on plats in out-of-door drill-sown beds, experiment 36 on an alkaline soil, all of which had been heated in a moist condition at a temperature of not less than 80° C. for not less than 10 minutes,[2] and experiments 45, 47, 49, and 51 on a sand which had

[2] This temperature is probably high enough to eliminate damping-off organisms. Tests by Dr. Theodore C. Merrill indicate that the three most virulent parasites so far worked with are killed by placing agar tube cultures for 10-minute periods in water at the following temperatures: *Pythium debaryanum,* 65° C.; *Corticium vagum,* 50° C. for mycelium and 60° C. for sclerotia; *Fusarium moniliforme,* 70° C. Both the Pythium and Fusarium cultures contained spores. The possibility of the survival of oospores which would not be capable of germination for several months was apparently eliminated by the writer, who retained Dr. Merrill's heated Pythium tubes and made final transfers from them 7½ months after heating, still without securing growth. Plenty of typical oospores were present in the part of the heated culture from which transfers were made.

been treated with sulphuric acid followed later by lime. The other experiments included in the graphs were on autoclaved sandy loams in pots in the greenhouse. In these graphs are included all of the results in which the same groups of strains were used repeatedly in different experiments. In figure 1, the values plotted for experiments 36, 49, and 51 are for the number of seedlings which appeared above ground, the heavy inoculations and favorable conditions for damping-off in these experiments being such that even weak strains caused heavy losses and the survivals therefore do not give differential results. Comparison of the survival data in the other experiments in figure 1 with the emergence data for the same strains in that figure and in figure 10 indicates that the strains best able to reduce survival are also the ones best able to reduce emergence.

While the data presented in the graphs are not entirely consistent, it is very evident from them that strains 147, 213, and in a lesser degree 206 were regularly more virulent than most of the strains in tests conducted several years apart on different species of Pinus. It is also evident that certain strains of 186 and 189 which appear in figure 2 are quite regularly of low or doubtful virulence. Strains 50, 183, 192, 211, 212, 230, and 233, whose virulence is apparently intermediate, show a greater variability. In experiments 36, 45, 47, 49, and 51, in which conditions especially favor parasitism, they may cause practically as serious loss as the regularly virulent strains, the best differential results being shown in experiments in which the disease is less favored. The apparent variation in the relative virulence of such strains in different experiments may, of course, mean that their virulence is differently affected by different conditions. It seems rather more probable that the variation in relative activity is to be classed as accidental variation, necessarily great with small units which are subject to numerous uncontrollable variables. It seems entirely possible, however, that part of the observed differences in relative activity may be due to differences, not in virulence, but in the ability of the different strains to maintain themselves saprophytically in different soils during the period between inoculation and the commencement of germination. For example, strains 230 and 233 came from a nursery in southwestern Kansas in which the soil-acidity exponent, as determined by Dr. L. J. Gillespie, of the United States Bureau of Plant Industry, is 8.4. It seems entirely possible that these strains, rather strongly parasitic in some of the experiments, including an experiment on the soil from which they were taken, might prove less able than strains from some other habitats to maintain themselves on some of the eastern soils used in the greenhouse tests. The source of strains 230 and 233 was furthermore a locality where high soil temperatures are to be expected. The fact that experiments 71 and 72, in which they showed the least virulence, were conducted in a colder greenhouse than any of the other tests may have had something to do with the lower activity indicated for these strains. Variation in the temperature requirements of different strains in accordance with the temperature of the source locality has already been demonstrated by Edgerton (35) for one of the anthracnoses. It is hoped later to determine the temperature and acidity preferences of these two strains as compared with the others used. It should be noted that the consistently weak strain No. 189 (fig. 2), was abnormal in habit, lighter brown, and produced fewer sclerotia than typical strains. The other strains appearing in the graphs showed no conspicuous morphological or cultural differences that were identical. The only other strain which was noticeably abnormal in culture was one from pine seedlings in Kansas, intermediate in habit and color between No. 189 and the typical strains and indicating little more virulence than No. 189 in the few experiments in which it was used. It does not appear in figures 1 and 2, but was included in the experiments reported in the following paragraph. Peltier (99) believes low sclerotium-forming capacity to be a sign of degeneration and low virulence; the writer's experience agrees with his as to virulence, but these two strains showed no other evidence of lack of vigor.

As a further check on the reality of the apparent differences in virulence between different strains, all of the original strains available at the time, a total of 29, were used in the practically duplicate experiments 71 and 72 and the relative survivals of the same strains in the two series mathematically and graphically compared (fig. 11). The very decided correlation between the two experiments indicated by the graph has a coefficient[3] of 0.813 ± 0.042, nineteen times its

[3] The correlation coefficient, a very useful thing for many kinds of biological work, which unfortunately has received little attention from plant pathologists, is explained by Secrist (124, p. 43 et seq.) and the process of computation described (124, p. 453–467). A shorter method of computation is given by E. Davenport (30, p. 465–467); the example he gives is of a series with a large number of varieties, in which the correlation table is employed. Davenport's method is, however, just as useful in such a case as this, in which the number of varieties is too small to make the formal table advantageous. In such a case the computation should be arranged as by Secrist (124, p. 460–461), but the guessed rather than the true mean used and Davenport's formula employed. If the coefficient is +1, the correlation is perfect; if it is 0 there is no correlation, and if −1, perfect negative correlation. The significance of a coefficient less than 1 is judged from its relation to its probable error. King (84), in an excellent discussion of correlation, gives rules for judging the degree of significance of the coefficient. The correlation coefficient has its greatest potential usefulness in examining apparent causal relations. It is so used in connection with the relation between the hydrogen-ion exponent and damping-off in considering figure 12 of the present bulletin. Interexperimental, or, as Harris calls them, "interannual" correlation coefficients of the sort used for these Corticium strains have been used by Norton (96, p. 51) in measuring the constancy of rust resistance of asparagus strains, by Harris (54) in demonstrating the constancy of differences in various characters between strains or individuals, and they appear to be useful for this purpose in the present case.

probable error. Peltier's results permit similar correlations for the 18 strains common to his experiments 1 and 1A on carnation cuttings and for the 22 strains common to experiment 1 on cuttings and experiment 2 on seedlings. The coefficients found are decidedly lower than those obtained from the experiments on pine, 0.51 ± 0.117 for the experiments on cuttings and 0.36 ± 0.124 for the comparison of the results on cuttings with the results on seedlings, but nevertheless indicate some interexperimental correlation for the same strains and therefore inherent differences in parasitic ability between the different strains.

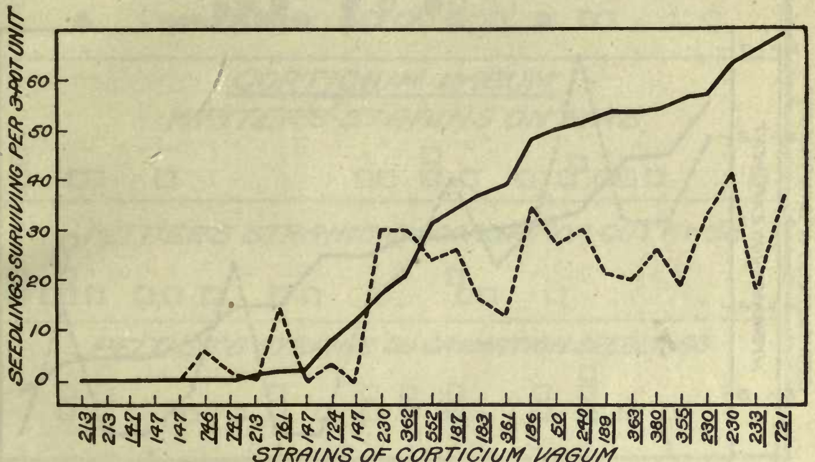


FIG. 11.—Diagram showing the comparative virulence of 29 strains of *Corticium vagum* in two successive inoculation experiments on *Pinus resinosa*. The results in experiment No. 71 are shown by the solid line, the strains being arranged from left to right in the order of descending virulence indicated by the number of seedlings surviving in this experiment. The results from the use of the same strains in experiment No. 72 are shown by the broken line. The obvious correlation between the two curves (coefficient 0.81 ± 0.04) indicates a real difference in virulence between the different strains. The strains indicated by the underscored numbers are original strains and those not underscored reisolations from the original strains in earlier inoculation experiments on pine seedlings.

In the work on pine seedlings, with the possible exception of strains 230 and 233, there was no evidence of attenuation in artificial culture. Strains 147 and 213, isolated in 1910 and 1911, respectively, seemed as strongly parasitic in experiments 71 and 72 (1917 and 1918) as any of the five strains isolated in 1916 or the six strains isolated in 1915.

Of the 20 strains above mentioned, three pairs were isolated under such conditions and showed such later agreement in performance as to indicate their individual identity. For the purposes of consideration in the following paragraph, the one of these probably duplicate strains which happens to have the higher number was eliminated from each pair. The survival figures in pots inoculated with the 17 strains remaining, giving the mean of the results in experiments 71 and 72, are shown graphically in figure 13, together with the results of some of Peltier's experiments in which other strains were used. Percentages of seedlings damped-off after germination are not included in these and most of the other data on pines because the most virulent strains often entirely prevent germination, and no value for subsequent loss is obtainable. The grouping of most of the writer's strains at the least virulent end of the register (that is, the one with the highest number of living seedlings) is of some interest. The distributions based on the two experiments considered separately

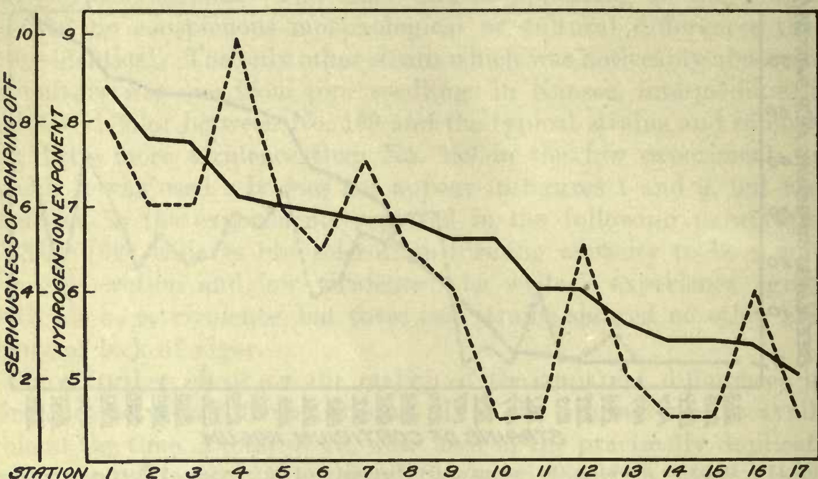


FIG. 12.—Diagram showing the relation between damping-off of conifers (broken line) and soil acidity (solid line). The acidity of soil samples from the different nurseries, determined by Dr. L. J. Gillespie, is reported as P_H7, indicating approximate neutrality while P_H6 indicates ten, and P_H5 one hundred times as great a hydrogen-ion concentration as P_H7; therefore the lower the hydrogen-ion exponent line, the greater the acidity. The seriousness of damping-off at each nursery is on an arbitrary scale in which nurseries with negligible loss are rated as 1, and the nursery which suffered most is rated as 10. These values are estimates, though for some of the nurseries extensive counts were available on which the estimates were based.

agreed very well in this grouping. The minor group at the end of extreme virulence is not taken to indicate an actual grouping but, rather, an artificial one, due to the fact that both the strongest strains and some less strong were thrown into the same group by the lack of additional seedlings for the stronger strains to kill. This lack of additional seedlings constituted a limiting factor. In other words, conditions favored damping-off even in these two experiments too much to permit completely differential results for the more virulent strains. Despite this artificial limit preventing the full variability becoming evident, the coefficient of variability of the survivals had the high value of 63±9.7 per cent. The graph indicates also a decided, though less extreme, degree of variability for Peltier's strains on carnations; the survivals for the 18 strains which he used in both of his experiments on cuttings have a variability coefficient of 29±3.5 per cent and the 23 strains in experiment 2 on seedlings 55±6.9 per cent.

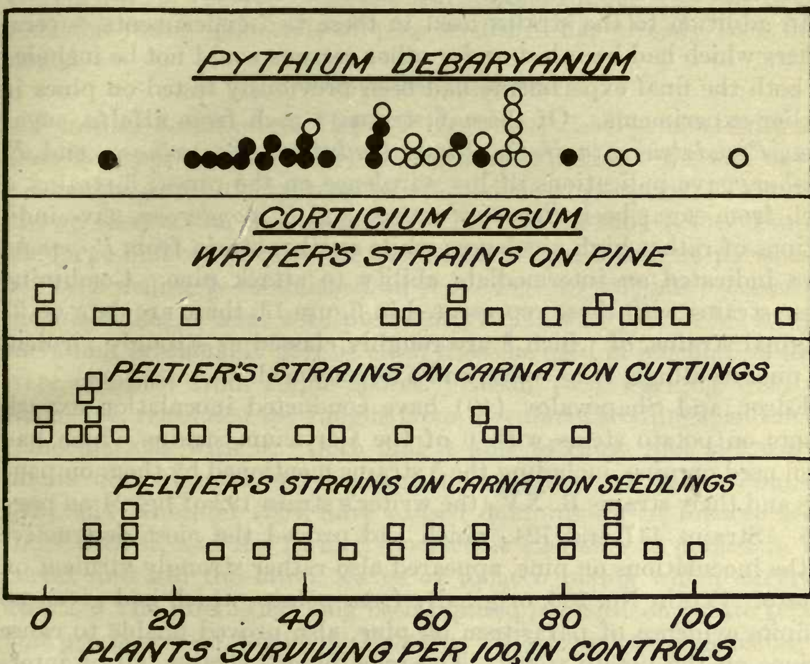


FIG. 13.—Diagram showing the results of inoculations with 17 strains of *Corticium vagum* and 35 strains of *Pythium debaryanum*, arranged in decreasing order of virulence from left to right, as indicated by the survivals in pots of pine seedlings artificially inoculated with them. The Pythium results represent the mean survivals in 5 pots inoculated with each strain in each of experiments Nos. 66, 67, and 68. Each point located is therefore based on the results in 15 pots, 10 of *Pinus banksiana* and 5 of *P. resinosa*. The Corticium results on pine represent 5 or 6 pots each, in two experiments (Nos. 71 and 72) on *P. resinosa*. The outline circles represent *P. debaryanum* strains from East Tawas, Mich.; the solid circles represent strains from other localities. The second row of squares shows the sum of the results in Peltier's experiments Nos. 1 and 1a (99, his table 3). The lowest row of squares shows his results in experiment No. 2 (his table 4).

The strains represented in figure 13, as used on pine, include 1 from bean, 2 from potato, 1 from sugar beet, 1 from Elaeagnus, 2 from *Picea engelmanni*, and 10 from *Pinus resinosa*, *P. ponderosa*, and *P. banksiana*. Two were from Washington, D. C., 2 from New York, 1 from Ohio, 4 from Michigan, 4 from Minnesota, 1 from Nebraska, 2 from Kansas, and 1 from California. The sources of these strains are widely distributed both as to host and locality; they are rather more representative of the country as a whole geographically than the strains in the larger of Peltier's experiments, though less representative as to host sources. The number is too small to justify conclusions as to the proportion of *Corticium vagum* strains which can be expected to prove strongly virulent on pine. The data are offered merely as a beginning, to which it is hoped experimenters with other strains of *C. vagum* will make additions.

In addition to the strains used in these two experiments, several others which had been lost or for other reasons could not be included in both the final experiments had been previously tested on pines in earlier experiments. Of these, 6 strains, 1 each from alfalfa, sugar beet, *Pseudotsuga taxifolia*, *Pinus banksiana*, *P. resinosa*, and *P. strobus*, gave indications of low virulence on the pines; 3 strains, 1 each from sugar beet, *Pinus sylvestris*, and *P. ponderosa*, gave indications of rather high virulence; while another strain from *P. ponderosa* indicated an intermediate ability to attack pine. Combining these strains with those represented in figure 13, there are data on 27 original strains, of which 8 are roughly classed as strongly virulent on pine seedlings, 14 as weak, and 5 as intermediate.

Edson and Shapovalov (40) have conducted inoculation experiments on potato stems with 6 of the Corticium strains which had been used on pine, including the 5 strains mentioned by them on page 218 and their strains R. XV (the writer's strain 192 of fig. 2) on page 215. Strains 147 and 724, which had proved the most destructive in the inoculations on pine, appeared also rather strongly virulent on potato. Strain No. 186, originally from potato, which had given no definite evidence of parasitism on pine, also proved unable to cause lesions on the potato stems. The remaining 3 strains, all of intermediate virulence on pine, gave results on potato which were less indicative of agreement with the order of virulence on pine. The data suggest that strains strongly parasitic on potato are likely to be strongly parasitic on pine, and vice versa, but the agreement between their results and the writer's is not sufficiently complete to establish the point.

FUSARIUM SPP.

Fusarium is often found on or in damped-off seedlings (24, 46, 60, 94, 120, 137, 141, 142). The early inoculation experiments, conducted in the main with strains not sufficiently described to allow their identification, have been recently summarized (68, p. 537), together with descriptions of inoculation experiments on pine seedlings with four commonly recognized species of Fusarium. These, though not followed by reisolation, gave rather definite evidence that *Fusarium moniliforme* Sheldon was decidedly parasitic and *F. solani* less strongly so. *Fusarium ventricosum* Appel and Wollenw. was indicated as more strongly parasitic than *F. solani*, but in a single test only and with a culture of doubtful purity. *Fusarium acuminatum* E. and E. gave no evidence of parasitism. These results agreed with those of Spaulding (137) in indicating that the ability to attack seedling conifers is not limited to a single species of Fusarium and that *F. moniliforme* is one of the more virulent. The statement by Hartig (61, p. 147–150) that a Fusariumlike fungus was able to corrode the young epidermis of pine seedlings has already been mentioned.

PYTHIUM DEBARYANUM.

Pythium debaryanum Hesse (*Artotrogus debaryanum* Atkinson, *Lucidium pythioides* Lohde) has been known since 1874 (74, 86) as a common cause of damping-off of various angiosperms. The first known observation was made by De Bary about 1864 (74). Despite the large number of hosts on which it has been listed, its parasitism has been definitely established on few. Peters (100) has successfully inoculated sugar beets with pure cultures; at least part of his strains, including presumably part or all of those he used in inoculation tests, were obtained from single spores. Edson (38) working with the same host, reisolated the fungus from inoculated seedlings, and made reinoculations with it. Both find it able to cause root sickness of plants not attacked early enough to be killed outright. Johnson (82) and Knechtel (85) have caused damping-off of tobacco seedlings with it, and the former reported it also able to persist in the cortex and kill the lower leaves of tobacco plants which survived attack. The fungus has long been reputed parasitic on potato tubers and has now been found by Hawkins (70) to be the chief cause of the rot known as "leak" in California. Peters (99) made successful inoculations with pure cultures on cuttings of Pelargonium. Most of the reports of parasitism, however, have been based on microscopic examination or more or less crude inoculation experiments. Noteworthy among the latter are those reported by Hesse (74) on *Camelina sativa* in the original description of the fungus. These were made before pure-culture technique had come into use with fungi, but were so thoroughly checked by microscopic observations at every step in the process that they must be admitted as very good evidence of the parasitism of the fungus. A number of reported angiospermous hosts are listed by Butler (23), Voglino (143), and Johnson (82, p. 34, footnote, and p. 35). Reinking (107) recently reported *Canica papaya* as attacked. A host which the writer has not found in the literature is rice, found by Dr. Haven Metcalf seriously attacked in the seedling stage in a field in South Carolina. A second apparently new host for the fungus is fenugreek (*Trigonella foenum-graecum*). The writer found oospores typical of *Pythium debaryanum* in the tissues of damped-off seedlings received by Prof. William T. Horne, from Sonoma County, Calif., with the statement that the disease was seriously affecting the stand. The fungus was easily isolated, and the results of successful inoculations on pine with the cultures obtained are included in Table V (p. 47). A fungus resembling *P. debaryanum* was also found in damped-off cowpea (*Vigna* sp.) seedlings grown in rotation with pines at a Nebraska nursery.

Pythium equiseti Sadebeck, reported as parastic on the prothallia of *Equisetum arvense*, was successfully used by Sadebeck (117) in crude cross-inoculations direct from *E. arvense* to potato tubers. De Bary (5) reversed the direction of the experiment between cryptogamous and phanerogamous hosts by successfully inoculating prothallia of *Equisetum arvense* with *Pythium debaryanum* directly from diseased Lepidium seedlings. He also secured positive results on prothallia of the fern *Todea africana* by the same method. The Equisetum prothallia he found to be especially favorable media on which to develop *Pythium debaryanum*. Fischer considers the fungus found by Bruchmann (17) and Goebel (49) on prothallia of *Lycopodium* sp. as probably identical with *P. debaryanum*. A careful reading of the original articles is sufficient to show that the symbiotic fungus which they described was an entirely different organism. *Saprolegnia schachtii* and *Sporodospora jungermanniae*, reported on two of the Hepaticæ, are of doubtful position (42, p. 403), though Butler (23, p. 89), after a survey of the literature, apparently favors the view that the former is distinct from the damping-off fungus. De Bary (5) reported Vaucheria and Spirogyra apparently immune against *P. debaryanum*.

Early references to *Pythium debaryanum* in connection with gynosperms seem to have been based on the probability that it would be found to be the cause of damping-off in conifers (6; 97; 134, p. 27). The first actual finding of the fungus in any gymnosperms of which the writer is aware is indicated by a label marked *Pythium debaryanum* in the handwriting of Mrs. Flora W. Patterson on a package of coniferous seedlings from a New York nursery collected in 1904.[4] The seedlings, judging from the several rather long cotyledons and the fact that both cotyledons and primary leaves are denticulate, are probably of one of the species of Pinus having medium-sized seed. In 1908 Dr. R. J. Pool, of the University of Nebraska, and his student, Mr. H. S. Stevenson, obtained in culture from damped-off coniferous seedlings a nonseptate fungus which was probably *Pythium debaryanum*, but which formed no distinctive spores on the media on which it was grown. A year later the writer obtained the fungus from pine seedlings at the same nursery and reported it as

[4] In the Office of Pathological Collections, United States Bureau of Plant Industry.

parasitic on pines in preliminary inoculation experiments (62). In 1910 Spaulding (137) found it on spruce in New York, and Hofmann (76) later made successful inoculations on both pine and spruce seedlings, using *P. debaryanum* cultures both from aerial trap plates and from recently damped-off seedlings of cabbage, radish, and Russian thistle (*Salsola tragus*). Hofmann's work, detailed notes of which the writer has been permitted to examine, was done with cultures which were contaminated by molds, but was checked up by microscopic examination of the lesions resulting, which showed the affected tissues filled with nonseptate hyphæ. His results are taken as a rather strong indication that *P. debaryanum* attacks spruce as well as pine and that the fungus attacking conifers is physiologically as well as morphologically identical with that causing the damping-off of angiosperms.

There thus appears from the literature to be reason to believe that *Pythium debaryanum* is parasitic on representatives of two groups of the Pteridophyta and on gymnosperms, as well as on various monocotyledons and dicotyledons, a range of hosts not only remarkable but perhaps unequaled in our present knowledge of plant parasites. Final published proof of parasitism seems to be available for three or four species of dicotyledons only. Additional inoculations on conifers with strains isolated from various other hosts are reported in the present bulletin. Some of the detailed evidence necessary for complete proof of the parasitism of the Pythium on conifers, lacking in experiments previously reported because of the doubtful purity of the cultures used and failure to reisolate and reinoculate with the organism, is also given here, together with evidence of the ability of the parasite to cause root sickness of pines too old to suffer from damping-off.

Descriptive data of interest on *Pythium debaryanum* have been supplied by Hesse (74), De Bary (5), Ward (144), Miyake (89), Butler (23), and Butler and Kulkarni (24). An important contribution to the physiology of the fungus and the factors controlling its passage through the tissues of one of its hosts has recently been made in the previously mentioned paper of Hawkins and Harvey (71).

IDENTITY AND ISOLATION.

The fungus in the writer's cultures referred to *Pythium debaryanum* Hesse has been so called for the following reasons:

(1) The morphological characters agree with those described and figured for *Pythium debaryanum* by other workers and with those of strains obtained from Dr. H. A. Edson under this name.

(2) The absence of zoospores in the writer's cultures agrees with the experience of others with *Pythium debaryanum* (2, 5, 23, 24, 38, 100), all workers with pure cultures having obtained zoospores infrequently, if at all. The earliest work by Hesse (74) in which zoospores were apparently produced

readily at certain times of the year was done before the development of pure-culture methods. Water cultures kept in the dark and in the light, at constant and at varying temperatures, with nutrient substrata consisting of steamed or outoclaved fragments of potato, carrot, sweet potato, turnip, sugar beet, corn meal or rice, nutrient agar, sugar-beet seedlings, and insects have all produced only sexual fruiting bodies and chlamydospores (the so-called conidia).

(3) The successful cross-inoculations, those which Edson (38) used on sugar-beet strains and the writer had found parasitic on pine and had used on pine, strains which Hawkins had found parasitic on potato tubers and Edson on sugar beets, confirm the work of Hofmann (77) in indicating that the Pythium which causes the damping-off pine is a parasite on entirely unrelated species of host plants, a commonly recognized characteristic of *Pythium debaryanum*.

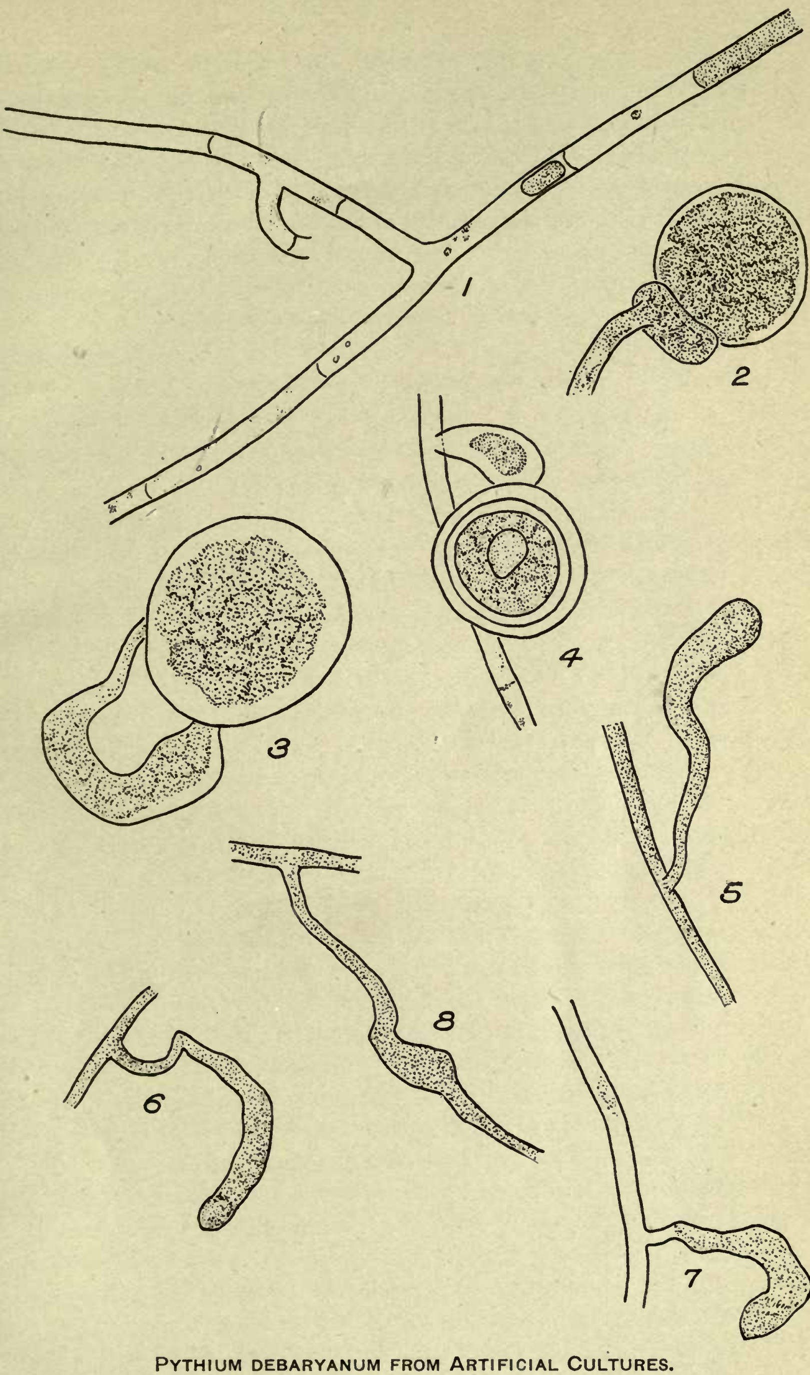
The organism is easily isolated from recently damped-off coniferous seedlings or from soil direct by placing the seedlings or a lump of soil at the edge of a Petri dish of solidified prune agar and transferring to tubes mycelium from the advancing edge of the resulting growth. It has been found in or obtained from damped-off conifers in California, Kansas, Nebraska, Minnesota, and the District of Columbia, as well as in cultures made by Mr. Glenn G. Hahn in Michigan. *Picea engelmanni*, *P. sitchensis*, *Tsuga mertensiana*, *Pinus nigra austriaca*, and *Pseudotsuga taxifolia* are the coniferous hosts from which cultures of *Pythium debaryanum* have been obtained. It has been isolated directly from soil not only in coniferous seed beds but from open grassland in California not adjacent to any seed bed or cultivated crop. Unless Mucor is abundant, Pythium is commonly obtained in apparently pure condition on the first transfer from the plate, as prune agar appears unfavorable for most bacterial growth while allowing rapid spread of the Pythium. On media made from prunes which taste sweet and with a total gross weight of not more than 40 or 50 grams per liter of medium, the Pythium will make a rapid growth, often extending radially 1 mm. per hour at temperatures in the neighborhood of 22° C. and produce both chlamydospores and oospores. A less valuable medium for isolation work, but more convenient for subcultures than any other which has been tested, is autoclaved corn-meal agar. The growth is not luxuriant, but spores are always formed and the cultures seem to be as long lived as those on any other medium, retransfer being rarely necessary more often than twice a year. Much stronger growth and more abundant fruiting is obtained on such media as sugar-beet or rice-stem agar, but the leathery surface of the culture on such media makes transferring difficult. On rice grains, corn-meal mush, beef agar, and on corn-meal agar plus 2 per cent dextose or sucrose no spores are formed and the cultures are short lived, though growth is heavy and on the last-named medium extremely rapid. On agar containing the juice from sour prunes or on corn-meal agar prepared without subjecting it to the high temperature of the autoclave, both growth and fruiting have been very poor or even lacking.

In both artificial cultures and in the tissues of coniferous and dicotyledonous hosts the numerous strains observed showed no conspicuous differences in the size or other characters of the spores produced, though noticeable and constant abnormality was found in one strain in the readiness with which spores were produced and in two strains in the ratio between chlamydospores and oospores in agar cultures. In the first-mentioned strain, obtained from pine in Kansas, and in cultures reisolated from seedlings inoculated with it, both chlamydospores and oospores are produced tardily and so scantily that it is often difficult to find them. In most strains, on the other hand, almost the entire contents of the mycelium are promptly emptied into the spores as soon as the limits of rapid vegetative growth are reached. In another abnormal strain from pine from the same locality, and in still another furnished by Hawkins from a California potato, chlamydospores are produced in large numbers, but oospores are few. In many other strains, including several from California, the opposite condition obtains, oospores in plate cultures being decidedly more numerous than chlamydospores. These peculiarities of particular strains seem to be fairly constant characters, the first abnormal strain mentioned having been under observation for more than three years without any change in its tendency to scanty fruiting, and the low ratio of oospores to chlamydospores having been constant during the shorter periods over which the observation of the other strains extended. In view of the small variation between different strains in the matter of speed of growth, a purely vegetative character, this variation in reproductive habit is somewhat surprising. The strain which produced spores infrequently was unquestionably parasitic, though it killed fewer seedlings than the average *Pythium debaryanum* strains. The strains with the high ratio of chlamydospores were both of at least average virulence on pine.

Oospores in the strains the writer has had in culture, whether examined in agar, in water cultures, or in root tissues, have ordinarily been somewhat larger than the diameter of 14 or 15 to 18 μ given in a number of the descriptions. The maximum range has been 12.8 to 20.6 μ, the same strain sometimes being well down within the usual size range and sometimes ranging from 17 to 20 μ. The largest oogones observed were 26 μ in diameter. Various stages of fertilization are shown in Plate I, figures 2 to 4. Chlamydospores attain a maximum diameter in the case of the limoniform intercalary forms of 32 μ, and spherical chlamydospores sometimes reach a diameter of 28 μ. There is no lower limit for these bodies, as under unfavorable conditions—e. g., in sour-prune agar—they are sometimes all less than 15 μ in diameter, and the smaller ones are little larger than the hyphæ which bear them. Both oogones and chlamydospores may be either terminal or intercalary.

The normal hyphæ are large, varying from 3 to 7 μ and sometimes more in diameter. Typical hyphæ, showing the false septa developed at the boundary of the protoplasm and the portions of the hyphæ which have been evacuated in the extension of the younger parts, are shown in Plate I, figure 1. At points at which the ends of hyphæ come in contact with the glass of the culture dish, peculiar contact swellings are produced (Pl. I, figs. 5 to 7), much the shape and size of antheridia, but not walled off from the adjacent hyphæ and having no apparent significance in the life history of the fungus. These are not always terminal (Pl. I, fig. 8). It is noteworthy that Hesse described contact swellings at the tips of the hyphæ just before penetrating the epidermis of *Camelina sativa.*

The asexual nonsporangial fruiting bodies of *Pythium debaryanum* are referred to as chlamydospores rather than as conidia, though in most of the previous literature the latter term has been used for them. Hesse called the terminal bodies conidia and the intercalary, gemmæ (74). It is believed that the best terminology and the one which should be followed for all fungi, as it now is for most, is that which limits the term conidium to a spore which is adapted primarily for aerial distribution or which is at least readily separated as soon as it is mature from the parent hypha from which it arises. The most typical conidium, in fact, is a spore which is abstricted by the parent hypha at maturity. The asexual spores of this Pythium remain attached to the parent hyphæ indefinitely even after the hyphæ are dead and empty. It is a common thing to find numbers of these bodies in water cultures, still attached to hyphæ which are so completely empty that it is only with favorable lighting that their thin colorless walls can be seen. So firm is the attachment that vigorous shaking is required to release any considerable proportion of the spores. It seems probable that in nature the spores are released chiefly as a result of the destruction of the hyphæ walls by bacteria. While there is reason to think that *Pythium debaryanum* is sometimes disseminated by wind, it is by no means certain that it is through the medium of these spores. It is true that these bodies have thinner walls than are commonly found in chlamydospores of some other fungi, but they have somewhat thickened walls as compared with the vegetative hyphæ, and they are commonly intercalary. These facts, and the indications that they are better able to withstand unfavorable conditions than are the hyphæ, all tend to entitle them to rank as chlamydospores. De Bary (5) speaks of them as "dauerconidia." Their ability to stand drying is not entirely demonstrated, but is indicated by the relative longevity of the fungus on different media. On beef agar and on rice, on which no spores are



PYTHIUM DEBARYANUM FROM ARTIFICIAL CULTURES.

FIG. 1.—Hyphæ, showing old portions of hyphæ and false septa separating them from the portions still containing protoplasm. FIGS. 2 to 4.—Various stages of oospore formation. FIGS. 5 to 8.—Hyphal swellings at points of contact with glass. From camera-lucida drawings.

formed, a few tests indicate that the fungus is very short lived, sometimes dying in a month. On media on which spores are produced, transfers any time before the sixth month, and often as late as the tenth month, start immediate growth on fresh media. This is true even for strains which produce few or no oospores. The immediate commencement of growth from cultures 3 or 4 months old is taken as an indication that the new growth results from the asexual spores, as oospores are commonly believed to require a resting period of five or more months before they are able to germinate (5, 38).

INOCULATION ON STERILIZED SOIL.

Pythium debaryanum has been used in inoculation in pots of recently autoclaved soil in 16 different series of tests. In 10 of these, fragments of agar cultures were scattered over about one-fourth of the area at the side of each pot when seed was sown; in 2 of these 10 and also in 2 other tests some pots were inoculated over their entire surface. In every one of these 12 heavily inoculated series positive results were indicated by smaller emergence and where any considerable number of sprouting seeds escaped the fungus by heavier damping-off loss in the inoculated pots than in the controls. In some cases the fungus killed all or practically all of the seed or seedlings in the inoculated pots before they emerged from the soil.

In a total of 7 series, part or all of the pots received lighter inoculations, consisting of one or two small fragments of an agar culture placed just below the surface of the soil at the edge of each pot. In 5 of these success was indicated. In the sixth and seventh also of these lightly inoculated sets, there was more damping-off in the inoculated pots than in the controls, but the difference was negligible. The damping-off caused by light inoculations was in general distinctly less than that resulting from broadcast inoculations. To sum up the evidence: Sixteen separate experiments were conducted with *Pythium debaryanum* on pine seedlings in autoclaved soil, and in every one fewer seedlings survived in the inoculated pots than in the checks; the difference in most of the experiments was large.

Of the successful inoculation experiments—that is, those in which the difference between the inoculated pots and the checks seemed significant—9 series included jack pine (*Pinus banksiana*), 7 series western yellow pine (*P. ponderosa*, Colorado and New Mexico seed), and 3 series red pine (*P. resinosa*). In addition to the pines, Douglas fir (*Pseudotsuga taxifolia*, Colorado seed) was grown in two large plats in one of the earlier series, one being inoculated over its entire surface with *Pythium debaryanum*. Because of the poor quality of the seed in the test on Douglas fir, too few seedlings were obtained to furnish a decisive test, but the difference in the emergence in the inoculated plat and the control affords preliminary evidence that

Pythium can cause the "germination-loss" type of damping-off in Douglas fir as well as in species of Pinus. Of the seeds sown in the control plat 43 produced seedlings which appeared above the soil, while only two seedlings appeared from an equal number of seeds sown in the inoculated plat.

Altogether, 38 strains, excluding reisolations, have been tested on one or more of the 3 pine species. Strains from both the Pacific coast and the eastern United States and from a number of hosts other than pines were among those used. With the exception of two or three strains from a pine nursery in Michigan, the use of which was followed by so little damping-off as to leave their parasitism uncertain, all of the strains proved parasitic under favorable conditions, though some were more virulent than others. The positive results in the 14 successful experiments are based on the comparison of a total of approximately 1,160 inoculated pots with 195 control pots.

TABLE III.—*Inoculation experiments with Pythium debaryanum in pots of sterilized soil.*

Series, experiment number, and host.	Pythium strain.		Number of pots.	Inoculation method.	Results.		
	No.	Initial strain from which it was reisolated.			Emerged (per 5-pot unit).	Damping-off after germination (per cent).	Survival (per 5-pot unit).
SERIES A.—Initial inoculations:							
No. 58, Pinus banksiana	218		5	Agar cultures broadcast at one side of pot.	1	100	0
	Controls		5	No inoculum	74	0	74
	do		5	do	82	0	82
No. 58, Pinus ponderosa	295		5	Agar cultures at single point in each pot.	41	28	30
	Controls		5	No inoculum	55	0	55
No. 62, Pinus banksiana	258		5	Agar cultures broadcast at one side of pot.	16	81	3
	do		5	do	18	89	2
	Controls		5	No inoculum.	90	0	90
	do		5	do	82	0	82
	do		6	do	82	0	82
	338[a]		5	Agar cultures broadcast at one side of pot.	14	72	4
	347[a]		5	do	3	67	1
	348[a]		5	do	13	67	4
	Control[a]		5	No inoculum	78	0	78
SERIES B.—Reisolated strains:							
No. 62, Pinus banksiana	338	No. 295 (in P. ponderosa, expt. 58).	5	([b])	14	72	4
	Controls		5		78	0	78

[a] A different soil used in these pots from that used with strain 258 and the first three control units.
[b] All inoculations with fragments of agar cultures scattered broadcast at one side of the pot, including about one-fourth of its area. Nothing was added to the controls in experiment 62, but sterile agar was added to the controls in experiments 66, 67, and 68.

TABLE III.—*Inoculation experiments with Pythium debaryanum in pots of sterilized soil*—Continued.

Series, experiment number, and host.	Pythium strain.		Number of pots.	Inoculation method.	Results.		
	No.	Initial strain from which it was reisolated.			Emerged (per 5-pot unit).	Damping-off after germination (per cent).	Survival (per 5-pot unit).
Series B.—Reisolated strains—Continued.							
No. 66, Pinus banksiana	338	No. 295 (in P. ponderosa, expt. 58).	5	(a)	9	67	3
	345	No. 218 (in P. banksiana, expt. 58).	5	(a)	15	33	10
	414	No. 258 (in P. banksiana, expt. 62, 2d unit).	5	(a)	36	25	27
	415	do	5	(a)	59	10	54
	419	No. 348 (in P. banksiana, expt. 62).	5	(a)	25	100	0
	450	No. 347 (in P. banksiana, expt. 62).	5	(a)	41	72	11
	Controls		25		75	14	64
No. 67, Pinus banksiana	338	No. 295 (in P. ponderosa, expt. 58).	5	(a)	7	57	3
	345	No. 218 (in P. banksiana, expt. 58).	5	(a)	24	37	15
	414	No. 258 (in P. banksiana, expt. 62, 2d unit).	5	(a)	57	24	44
	415	No. 258 (in P. banksiana, expt. 62, 1st unit).	5	(a)	30	37	19
	419	No. 348 (in P. banksiana, expt. 62).	5	(a)	62	65	22
	450	No. 347 (in P. banksiana, expt. 62).	5	(a)	53	27	39
	Controls		23		87	5	83
No. 68, Pinus resinosa	338	No. 295 (in P. ponderosa, expt. 58).	5	(a)	85	26	63
	345	No. 218 (in P. banksiana, expt. 58).	5	(a)	76	24	58
	414	No. 258 (in P. banksiana, expt. 62, 2d unit).	5	(a)	98	14	84
	415	No. 258 (in P. banksiana, expt. 62, 1st unit).	5	(a)	92	11	82
	419	No. 348 (in P. banksiana, expt. 62).	5	(a)	95	45	52
	450	No. 347 (in P. banksiana, expt. 62).	5	(a)	84	40	51
	Controls		18		104	0	104

[a] All inoculations with fragments of agar cultures scattered broadcast at one side of the pot, including about one-fourth of its area. Nothing was added to the controls in experiment 62, but sterile agar was added to the controls in experiments 66, 67, and 68.

As has been stated, securing positive results did not always mean that the control pots remain uninfected. Even with the most careful treatment and the use of boiled water throughout the experiment it proved difficult to keep the control pots entirely free from damping-off. Cultures from seedlings which damped-off spontaneously in control pots indicated that Pythium as well as Fusarium may be introduced by accident, even when insects, birds, and rodents are excluded. This agrees with the evidence of Hofmann (77) that *Pythium debaryanum* is sometimes disseminated by wind, despite its apparent lack of adaptation to wind distribution. It is also indicated, however, that unheated tap water increases damping-off when used on control pots and probably carries this semiaquatic fungus. Notwithstanding infections in the controls of a number of the experiments, it is believed that the large number of pots whose results have been considered in drawing conclusions, the fact that the Pythium pots lost more heavily than the controls in every one of the 16 experiments, and the magnitude of the differences between both the emergence and subsequent damping-off figures for the inoculated pots and the controls in most of the experiments establish the parasitism of the fungus in inoculation on autoclaved soil without it being necessary to present all the evidence in detail. The pot series which involved reisolation and reinoculation (Table III), together with the results given for other purposes in Tables V and VI, seem sufficient by themselves to establish a parasitic relationship.

REISOLATION AND REINOCULATION.

In a number of the experiments dead seedlings in the inoculated pots were examined and typical Pythium hyphæ and spores were found. In three of the experiments in which the controls remained entirely free from disease up to the time the experiment was closed, reisolations and reinoculations were made in accordance with the usual rules of proof. The results are given in Table III.

From Table III it will be seen that five strains reisolated from *Pinus banksiana* and one strain reisolated from *P. ponderosa* gave positive results in pots of *P. banksiana* and *P. resinosa*. In addition to the reinoculations shown in the table, the strain reisolated from *Pinus ponderosa* (No. 338) was again reisolated in duplicate from *P. banksiana* in experiment 62, and both these secondary reisolations gave cultures which were parasitic on *P. banksiana* and *P. resinosa* in subsequent inoculations.

That the organisms reisolated were actually the same as those used in the initial inoculation is indicated not only by the absence of disease in the control pots of experiments 58 and 62, but by the distinctive characters of some of the strains. In general, cultures reisolated from strongly parasitic initial strains were themselves strongly parasitic and vice versa. This is shown by comparing the figures for the initial and reisolated strains, as shown in Table IV. Each figure represents the average results in 10 pots of jack pine and 5 of red pine in experiments 66, 67, and 68 combined. The figures are relative, the mean survival of 47 different strains used in all three experiments being taken as 10. A survival figure above 10 therefore means that the strain was less destructive than the average Pythium, and a figure below 10 indicates more than average virulence. As strain 218 was not used in these three experiments, strain 345 can not be compared.

TABLE IV.—*Comparative virulence of original cultures and reisolated strains of Pythium debaryanum in experiments 66, 67, and 68.*

Pythium strain.	Description.	Relative survival.	Pythium strain.	Description.	Relative survival.
No. 258	Original culture	16	No 409	Reisolated from 338	9
No. 414	Reisolated from 258	12	No. 347	Original culture	4
No. 415	do	12	No. 450	Reisolated from 347	7
No. 295	Original culture	4	No. 348	Original culture	10
No. 338	Reisolated from 295	4	No. 419	Reisolated from 348	4
No. 408	Reisolated from 338	6			

These figures are not absolutely consistent, but are to be viewed as contributing to the evidence furnished by the absence of damping-off in the control of experiments 58 and 62 that the cultures reisolated in those experiments were actually identical with the original strains. A further proof of this identity is in the fruiting tendencies of the strains. Both Nos. 414 and 415, the strains reisolated from original strain 258, exhibited the peculiarly sparse spore production which has been characteristic of strain 258 for the entire period during which it has been in culture. The other reisolated strains, taken from pots inoculated with normally fruiting strains, all showed normal spore production.

PURITY OF CULTURES.

A slight deficiency in the evidence as to the parasitism of *Pythium debaryanum* both in the writer's work and apparently in all previous investigations except those of Peters (100) and possibly Knechtel [5] is the lack of single-spore cultures. The large number of strains which have remained apparently pure through numerous subcultures and have retained their individual characteristics as to virulence and fruiting tendencies (one strain having been carried on artificial media continuously for eight years without material change) give very strong justification for believing that the cultures used were pure. In three early inoculation tests the cultures used were afterwards found to have been contaminated by bacteria carried by mites; the positive results obtained in these three were the basis of the ear-

[5] Knechtel's work in Rumanian has been available to the writer only in the German abstract, which makes an ambiguous statement on this point.

liest report of pathogenicity (62), but have not been used as evidence in the present bulletin, though the contaminating bacteria in one of them, when tested independently, showed no evidence of parasitism. In all the experiments mentioned in the foregoing as giving positive results with Pythium the cultures used were apparently pure.

Cultures from single chlamydospores should be reasonably easy to secure, part of the chlamydospores in water cultures being separable from the mycelium by vigorous shaking, and further inoculation tests with cultures so obtained are probably desirable. The experiments so far conducted are believed to be sufficiently conclusive, however, for all practical purposes. For isolation of absolutely pure lines of this or any other cœnocytic fungus, it is evident, as pointed out by Dr. W. H. Weston (146), that isolations should be made from the uninucleate swarm spores. For the determination of the bare fact of pathogenicity such a refinement would be superfluous.

CROSS-INOCULATIONS.

The physiological identity of the Pythium attacking coniferous seedlings with the one which attacks dicotyledons is indicated by the results of several inoculation experiments. The last two experiments, one with jack pine and one with red pine for the host, are the most comprehensive and give results sufficiently decisive so that quotation of the corroborative evidence from earlier experiments is considered unnecessary. The results appear in Table V. Each unit consisted of five 3-inch pots except in the controls, in which 23 pots were used in the jack-pine experiment and 18 in that with red pine. In the second experiment, separate records were kept of the survival in each pot, and the probable error calculated from the controls was less than two seedlings per pot for a single pot, less than 0.9 for a mean of 5 pots, and less than 0.5 for the mean of the 18 control pots. While the number of controls was, of course, insufficient to furnish an exact basis for such a calculation, the small value found tends to confirm the impression gained from inspection of the table that considerable confidence can be placed in the results.

The difference appearing in Table V between jack pine and red pine in point of susceptibility to germination loss from Pythium agrees with field observations in Nebraska, the red pine at the Bessey Nursery, though on the whole more susceptible than jack pine to damping-off losses, having given indication of more resistance to the disease for the first week or two. Inoculations in other experiments on western yellow pine indicate that the strains which attack it are identical with those attacking jack pine and red pine.

The conclusion reached from the cross-inoculation results is that the Pythium causing damping-off of the three species of pine mentioned is identical with *Pythium debaryanum*, causing leak of potato tubers and the damping-off of seedlings of two dicotyledonous families.

TABLE V.—*Results of inoculations on jack pine and red pine with Pythium debaryanum from various hosts.*

Strain.	Host from which isolated.	Inoculation results.					
		On jack pine.			On red pine.		
		Emerged (per 5-pot unit).	Damping-off (per cent).	Survival (per 5-pot unit).	Emerged (per 5-pot unit).	Damping-off (per cent).	Survival (per pot).
	Dicotyledons:						
No. 131 [a]	Potato tuber	45	36	30	101	23	15.6
No. 810 [b]	Do	45	34	30	62	41	7.4
	Average potato	45	35	30	82	32	11.6
No. 294 [c]	Sugar-beet seedlings	50	8	46	79	36	10.2
No. 295 [c]	Originally potato strain 131, but twice inoculated on and reisolated from sugar-beet seedlings by Edson	28	32	19	62	48	6.6
No. 296 [d]	Sugar-beet seedlings	19	32	13	68	58	5.8
	Average, sugar beet	32	24	26	70	47	7.4
No. 529	Fenugreek seedlings [d]	36	31	25	102	26	15.0
No. 530	Do	60	49	31	108	22	16.8
	Average, fenugreek	48	40	28	105	24	16.0
	Conifers:						
No. 258	Western yellow-pine seedlings	58	9	53	109	17	18.0
No. 550	Sitka spruce seedlings	15	80	3	39	98	.2
No. 555	Engelmann spruce seedlings	42	29	30	45	70	5.0
	Average, spruces	29	55	17	42	84	2.6
	Controls	87	5	83	104	0	20.9

[a] Furnished by Mrs. C. R. Tillotson; has been used successfully on sugar-beet seedlings by Dr. H. A. Edson.
[b] Furnished by Dr. L. A. Hawkins: cause of leak.
[c] Furnished by Dr. H. A. Edson.
[d] Diseased material furnished by Prof. W. T. Horne.

VARIATIONS IN VIRULENCE OF PYTHIUM STRAINS ON PINE.

In *Pythium debaryanum* strains, as in the case of *Corticium vagum*, there appeared to be a considerable difference in the parasitic activity of different strains used in the same experiment. Figures 14, 15, and 16 show graphically the results from inoculations with different strains of *P. debaryanum* in all the experiments in which it was possible to compare directly the activity of different strains. All the inoculations involved at the time of sowing the addition to the soil of cultures on nutrient media in recently autoclaved 3-inch pots. In experiment 31C the inoculum fragments were scattered over the whole pot, in 31D at only one point in each pot, and in the others were distributed over about one-fourth of the pot's area. As noted elsewhere, the variations observed in the results may have been due in part to differences in the ability of the different strains to maintain themselves saprophytically in the soil used rather than entirely due to difference in virulence.

The data shown in figures 15 and 16 indicate in the first place rather more accidental variations in the results with Pythium than with Corticium (see figs. 1, 2, 10, and 11). The agreement between original and reisolated strains from the same original source is decidedly less good than in the case of Corticium (see experiments 71 and 72, figs. 10 and 11). In general, there are only two strains of

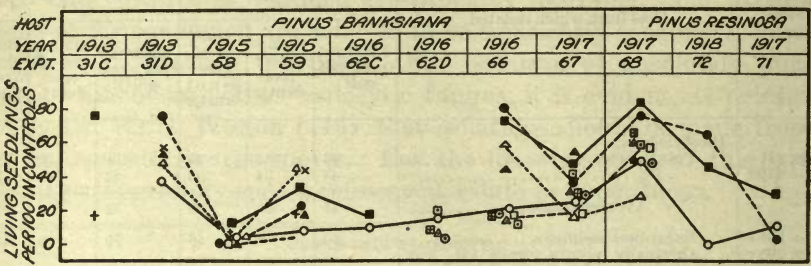


FIG. 14.—Diagram showing variations in virulence as indicated by the living seedlings in pots of autoclaved soil inoculated with different strains of *Pythium debaryanum*. For experiments Nos. 31 and 66 to 72, inclusive, the surviving seedlings at the end of two or three weeks after germination are shown. For the other experiments damping-off was so heavy in the inoculated pots that the survivals did not give differential results for the different strains, and the germinations are therefore shown. The reports are based for experiments Nos. 71 and 72 on 2 or 3 pots for each strain in each experiment, and for the other experiments on not less than 5 pots for each strain. In experiments Nos. 66, 67, and 68 the number of pots in each experiment for the strains whose reisolations were also used varied from 10 to 40 for each strain, the results of the separate 5-pot units being shown in figure 15. The strains indicated by the different symbols are as follows: *From potato:* ●=Strain 131, isolated in 1909, California. Furnished by Mrs. C. R. Tillotson. *From sugar beet:* ○=Strain 295 and its reisolations from pine. No. 295 was furnished by Dr. H. A. Edson as a reisolation of strain 131, after having been passed by him through two generations of sugar-beet seedlings. ▲=Strain 294, isolated in 1912. Furnished by Dr. Edson. △=Strain 296, isolated in 1912, Wisconsin. Furnished by Dr. Edson. ×=Strain 297, originally from pine, Nebraska, 1911. Passed through two generations of sugar-beet seedlings by Dr. Edson. *From pine seedlings:* +=Strain 255, Kansas, 1913. Chlamydospores numerous; oospores rare. ■=Strain 258 and its reisolations, Kansas, 1913. A sparsely fruiting strain. □=Strain 218 and its reisolation, Kansas, 1912. ⊙=Strain 347 and its reisolation, Washington, D. C., 1915. ⊡=Strain 348 and its reisolation, Washington, D. C., 1915. ◬=Strain 349, Washington, D. C., 1915. ⊞=Strain 354, Minnesota, 1915.

Pythium which can be said to have definitely shown difference in activity continuing through several years and on different species of pine. These are strains 295 and 258. As No. 258, the weak strain, has also been found abnormal in its fruiting tendencies, the evidence in these graphs does not indicate a decided difference in virulence between different typical strains of *Pythium debaryanum*. The other strain, which seems rather uniformly weaker than No. 295, is No. 131, which according to Dr. Edson's records was originally the same strain, No. 131 having been twice used in his inoculation experiments on sugar beets and strain 295 recovered from the second experiment. The apparent difference between this original strain and its supposed reisolation may possibly be due to the treatment given strain 131. Before it was used in any of the experiments shown but after it had been used by Dr. Edson, it was allowed to get very dry and was revived with great difficulty, growth being very slow. While it apparently recovered all of its normal growth qualities after one or two transfers, it is thought that this may possibly explain the apparently decreased virulence in the later experiments.

The failure to secure as definite indications of constant virulence differences as were obtained for several of the Corticium strains is believed to be in part due to a smaller actual difference between the different Pythium strains appearing in the graphs and in part to a larger accidental variation between results in pots inoculated with the same strain. The growth of Pythium on agar media is much more affected by variations in the substratum than is the growth of Corticium, and it is rather natural to expect greater variations when the two fungi are added to autoclaved soil. In experiments 66, 67, and 68 a number of strains not used in the earlier experiments were tested, in addition to the strains previously used. The survival results for all the different strains, both original and reisolated, 47 in all, are shown graphically in figure 16. The results in experiments 66 and 67, both on *Pinus banksiana*, are averaged and taken as the subject, while the results with the same strains in experiment 68 are made relative and shown by the broken line. The correlation between the performance of the same strains on the two species of pine is by no means as clear in the graph as it was in the case of the Corticium strains (fig. 11). The areas bounded by the broken line and

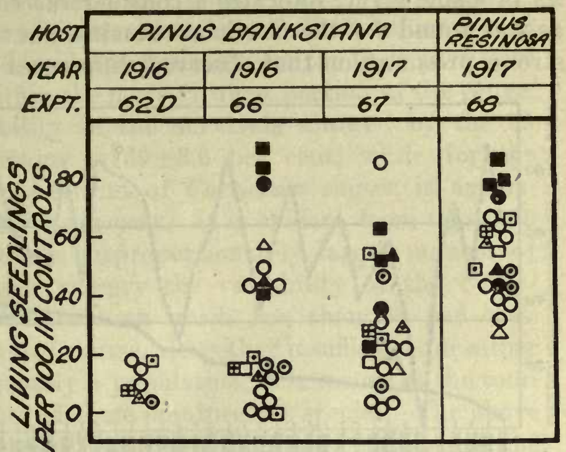


FIG. 15.—Diagram showing the results of inoculations with strains of *Pythium debaryanum*. This figure supplements figure 14, giving the results for original and reisolated strains independently. Each point plotted is based on the results in five pots. The object of this diagram is to give an idea of the degree of variability in the success of inoculations. An explanation of the symbols used will be found in the legend of figure 14.

the horizontal line showing the location of the mean for experiment 68 are much larger below the means than above it in the left-hand portion of the graph, while the reverse is true in the right-hand portion. To this extent the relative activity of the strains in this experiment agrees with the performance of the same strains in the two jack-pine experiments, as shown by the solid line. It can not be decided from an inspection of the graph whether there is a real agreement, in view of the large accidental variation present. However, the correlation coefficient, 0.446±0.079, five and one-half times its probable error, indicates a considerable correlation, not as good as was found for the Corticium strains, but sufficient to establish a strong presumption that observed differences in activity of the different strains in these inoculation experiments were in part actually due to differences in the capacity of the strains.

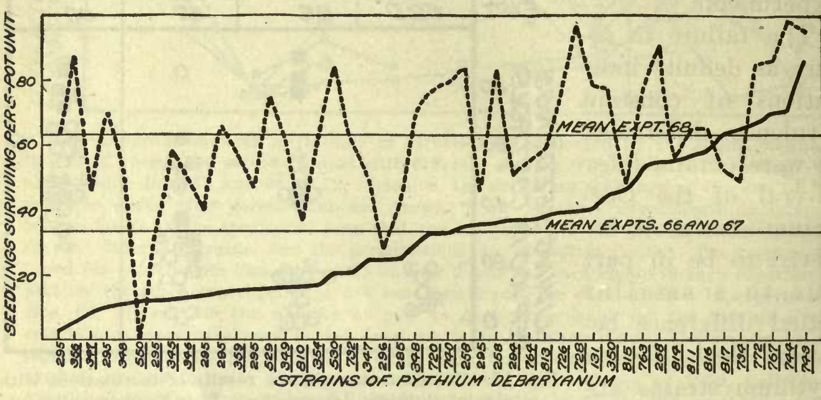


FIG. 16.—Diagram showing the comparative virulence of 47 strains of *Pythium debaryanum* in successive inoculation experiments on species of Pinus. The results in experiments Nos. 66 and 67 (on *Pinus banksiana*) are shown by the solid line, the strains being arranged from left to right in the order of descending virulence indicated by the number of seedlings surviving in those experiments. The results from the use of the same strains in experiment No. 68 (on *Pinus resinosa*) are shown by the broken line. Such correlation as there is between the two curves (coefficient 0.45±0.08) goes to indicate a real difference in virulence between the different strains. The strains indicated by the underscored numbers are original strains, and those not underscored are reisolations from the original strains in earlier inoculation experiments on pine seedlings.

It has been suggested in the foregoing that the difficulty in demonstrating constancy in the difference in virulence between the various strains of *Pythium debaryanum* is due in part to the lack of such extreme differences as were observed between the various Corticium strains. Figure 13 shows the distribution of the different original Pythium strains according to the virulence indicated in the three inoculation experiments of figure 16 (application to autoclaved soil at the time of sowing). Each value plotted is based on the average results in 15 pots. Of the strains used, 21 were from species of pine, 1 from spruce, 2 from potato tubers, 2 from fenugreek, 3 from sugar beet, and 6 from soil direct. Despite the considerable number of strains, they are not much more representative than the smaller number of Corticium strains experimented with. All of the strains from soil direct and 11 of the strains from pine were taken at approximately the same time from the same nursery in Michigan by Mr. Glenn G. Hahn; despite the fact that these were the most recently isolated of the strains used, nearly all of them proved weak in the inoculations. Of the 17 strains which proved the weakest (out of 35), all but 3 were from this Michigan nursery. The 18 strains from other sources (5 from California, 2 from Minnesota, 2 from Kansas, 1 from Wisconsin, 2 from an unknown locality, and 6 from Washington, D. C., representing two coniferous and three dicotyledonous host genera), as shown by solid circles in figure 13, for the most part were rather closely grouped within the more virulent portion of the range. The coefficient of variability in the survivals allowed by the 35 *Pythium debaryanum* strains is 39±3.6 per cent, while for the smaller number of original strains of *Corticium vagum* in experiments 71 and 72 it is 63±9.7 per cent. It is evident from figure 13 that if there had not been a disproportionately larger number of strains from the Michigan nursery the variability of the *P. debaryanum* strains would have been much less than 39 per cent. The number of strains was, of course, altogether insufficient for either fungus to represent adequately a population as immense as the total number of strains of either of these omnipresent species. The above data, however, contain the only available information of which the writer is aware on variation in the virulence of different strains of *P. debaryanum.*

The evidence as a whole, both from the results shown in figure 13 and the experience with 6 other strains which were not used in the experiments on which figure 13 was based, lead the writer to believe that most strains of *Pythium debaryanum* taken from lesions in plants are ordinarily likely to prove rather virulent parasites on pine seedlings. It further appears that the variation in virulence between the different strains of *P. debaryanum* on pine seedlings is less than the variation in strains of *Corticium vagum.*

PYTHIUM INOCULATIONS ON UNHEATED SOIL.

Inoculations with *Pythium debaryanum* were made in western Kansas on a fine sand containing little humus after treating the soil with acid followed by lime. Commercial sulphuric acid was applied at the rate of 14.8 c. c. per square foot of bed, followed two days later by 25.5 grams of air-slaked lime raked into the soil (0.16 liter of acid and 0.274 kg. of lime per square meter). The acid was diluted before applying with 256 volumes of water. The seeds were sown in drills, and inoculum was placed in the drills at the time of sowing. Each unit involved approximately 11 linear inches of drill, and all received equal quantities of seed. Three strongly parasitic strains of Pythium were used, and a total of 12 units of jack pine and an equal number of western yellow pine was inoculated with 12 interspersed units of each species as controls. The mean results are as follows:

Pinus banksiana.—Inoculated plats: Emerged, 64.2±4.9; died during the next 17 days, 25 per cent. Control plats: Emerged, 85.5±3.6; died during the next 17 days, 13 per cent.

Pinus ponderosa.—Inoculated plats: Emerged, 34.6±1.8; died during the next 9 days, 39 per cent. Control plats: Emerged, 45.4±1.3; died during the next 9 days, 25 per cent.

The difference in emergence apparently due to the inoculation is for the first species three and one-half and for the second nearly five times its probable error. While, of course, 12-unit means are insufficient to allow the calculation of entirely reliable probable errors, they give some idea of the amount of variability of the results and the confidence which can be given them. It is impossible to give any such expression applying directly to the damping-off percentages and their differences, for the reason that averages for this item have been made in the writer's work not by averaging the percentages for the individual units but by totaling all the seedlings and the dead seedlings on the plats to be averaged and recalculating the percentage from these figures. This seems the only safe method, as otherwise units in which germination is low by accident or by the action of parasites will be given an influence on the resultant mean entirely disproportionate to the number of seedlings which they contain. Average values for damping-off obtained by this method and by the method of averaging the percentages of the individual plats or pots are often very different; it not uncommonly happens that the units in which germination is lower than the average also have especially high damping-off percentages, both phenomena being caused by an unusual activity of parasites. In such case to average the percentages themselves usually gives a higher damping-off figure than to total the seedlings for the different units and redetermine the percentage, and the latter practice is considered the better. In the present case the differences in the damping-off percentages obtained by the two methods are not great. The figures obtained by averaging the percentages of the ultimate units are as follows:

Pinus banksiana.—Inoculated, loss 30.9±5.0 per cent; controls, loss 13.2±2.8 per cent.

Pinus ponderosa.—Inoculated, loss 40.0±5.1 per cent; controls, loss 24.1±3.3 per cent.

The differences between the inoculated and control plats in damping-off percentage were for the first species a little over and for the second a little under three times their indicated probable errors.

The results in general make it appear that the Pythium was able to kill some pines both before and after their appearance above the soil surface on the soil treated with the acid and lime. The control in this experiment did not receive the nutrient substratum added with the Pythium inoculum, but an experiment run under the same conditions at nearly the same time, in which seven strains of hyphomycetes with the same substrata entirely failed to decrease survival, indicates that the rice subtratum was not in itself the cause of the observed result. The rather weak action of the Pythium in these experiments stands out in sharp contrast to the results with *Corticium vagum* in the same experiments, practically all emergence being prevented by most of the Corticium strains used, some of which had proved less active than Pythium in tests on autoclaved soil.

In a soil in Nebraska, somewhat similar but with more humus, 5.5 c. c. (three-sixteenths fluid ounce) of sulphuric acid per square foot applied in solution at the time of sowing had been found greatly to decrease damping-off. In different parts of beds treated with acid from 10 to 17 days earlier, 96 plats, each 3 inches square, were laid out, and each plat was inoculated at the center. Interspersed with these were 96 plats set apart as controls. Emergence had already begun at the time of inoculation. Jack pine, red pine, and Corsican pine were the hosts, and three Pythium strains of known parasitism, growing in pieces of prune agar the size of peas, constituted the inoculum. The damping-off after emergence was less than 1 per cent higher for the inoculated plats than for the controls. Even such a light inoculation would probably have given some results in autoclaved soil, so the experiment indicates, as would be expected, that this acid-treated soil was less favorable for *Pythium debaryanum* than steamed soil.

On pots containing entirely untreated soil the following series of inoculations were made at the time of sowing the seed:

Inoculation at one point in each pot:

Experiment 25. Jack and western yellow pine, 1 pot of each inoculated; survival 13 days after emergence slightly greater in both than in the six controls.

Experiment 27. Jack pine, 73 pots, 27 controls; average emergence, 59 in inoculated pots and 56 in controls; damping-off, 39 per cent in inoculated pots and 37 per cent in controls.

Experiment 29. Jack, Corsican, and western yellow pine, 112 plats inoculated just as emergence commenced instead of at seed sowing, as in other cases, and 112 controls alternating with them; damping-off was less in the inoculated plats than in the controls.

Experiment 31. Jack pine, 8 pots inoculated, 8 controls; inoculated, emergence 33 per cent, damping-off 13 per cent, survival 198; controls, emergence 38 per cent, damping-off 26 per cent, survival 196.

Experiment 58A. Jack pine, 5 pots inoculated, 5 controls; inoculated, emergence 59 per cent, damping-off 32 per cent, survival 40; controls, emergence 51 per cent, damping-off 12 per cent, survival 45.

Inoculations at two points in each pot:

Experiment 26A. Jack pine, 3 pots inoculated, 4 controls; inoculated, emergence 29 per cent, as compared with 39 per cent in the controls; subsequent damping-off the same in both.

Inoculations at four points in each pot:

Experiment 58B. Jack pine, 5 pots inoculated, 5 controls; inoculated, emergence 51 per cent, damping-off 10 per cent, survival 46; controls, emergence 43 per cent, damping-off 22 per cent, survival 34.

Experiment 59A. Jack pine, 5 pots inoculated, 5 controls; inoculated, emergence 55 per cent, damping-off 2 per cent, survival 54; controls, emergence 50 per cent, damping-off 8 per cent, survival 46.

Of these experiments, No. 29 was in the original fine sandy soil of a nursery in Nebraska in which Pythium is commonly found native and damping-off losses are usually heavy. Experiments 58A and 59 were conducted on soil from the same source which had been kept dry in the laboratory for five years; experiments 25, 27, 31, and 58A were on greenhouse mixtures of sand and soil. In experiments 31, 58A, 58B, and 59 parallel inoculations were made on autoclaved portions of the same soil, with definitely positive results in three of the four cases. In the heated soil the results were positive, not only because of smaller losses in the controls but because the losses in the inoculated pots were actually heavier in the sterilized soil than in that untreated.

Inoculations broadcast:

Experiment 31. Jack pine, 8 pots inoculated, 8 controls; inoculated, emergence 31 per cent, damping-off 39 per cent, survival 129; controls, emergence 38 per cent, damping-off 26 per cent, survival 196.

Experiment 59. Jack pine, 5 pots inoculated, 5 controls; inoculated, emergence 58 per cent, damping-off 22 per cent, survival 45; controls, emergence 44 per cent, damping-off 2 per cent, survival 43.

Even with these broadcast inoculations the results on untreated soil were too indefinite to allow the drawing of positive conclusions. In both experiments much heavier losses than these resulted from inoculations on steamed soil. It is evident that experiments on sterilized soil do not always show what can be expected on ordinary soil. The same thing is indicated by the results of Edgerton with tomato wilt (36).

CONCLUSIONS AS TO THE PARASITISM OF PYTHIUM DEBARYANUM.

Pythium debaryanum has been found in low-altitude nurseries in all the species of conifers from which a serious effort has been made to obtain it, and its parasitism has been indicated in autoclaved soil on all of the conifers on which inoculation has been attempted. Therefore, although the work reported has been limited to a relatively small number of hosts, it seems likely that it will be found able to cause damping-off in most of the species of the Abietoideæ which suffer seriously from the disease. Just how active as a parasite it is under ordinary nursery conditions is yet to be proved. The results in inoculations on disinfected soil, together with the frequency with which the fungus has been isolated from seedlings in the nurseries, lead the writer to believe that it is an important cause of disease in the seed beds. Further experiments on unheated soil, however, are considered desirable.

RHEOSPORANGIUM APHANIDERMATUS.

CULTURAL STRAINS.

A culture of a parasite on radishes and sugar beets, described by Edson (39) under the above name, was obtained from him, and another strain, shown by Edson's records to be a subculture from the same original strain, was furnished by the department of plant pathology of the University of Wisconsin. In parallel cultures on solid media this fungus proved in many ways remarkably like *Pythium debaryanum*, reacting in practically the same way to the different media on which it was grown both in relative growth rate and in spore production. Mycelium, chlamydospores, oogones, antheridia, and oospores are not recognizably different from those of *Pythium debaryanum*. The oospores have seemed on the whole slightly larger and the mycelium a little more inclined to aerial growth than most of the *Pythium debaryanum* strains, but neither difference was sufficient to have diagnostic value. Swellings of the hyphæ occurred at points in contact with glass, just as with *Pythium debaryanum* (Pl. I, figs. 5 to 7).

In liquid cultures the Rheosporangium was readily distinguished from Pythium by the formation of the presporangia described by Edson. Autoclaved cylinders of turnip, 15 to 20 mm. long, cut with a 5-mm. cork borer, proved convenient bases for growth of both Rheosporangium and Pythium in water culture and quite as satisfactory as sterilized beet seedlings. Presporangia were also produced in autoclaved soil, and in a single lot of corn-meal agar they were formed abundantly in the agar in Petri dish cultures. In none of the writer's cultures, either with flies, sugar-beet seedlings, or turnip cylinders as nutrient bases, were mature escaped sporangia or swarm spores commonly produced.

The Rheosporangium was not obtained in any of the numerous cultures made from coniferous seedlings or from seed-bed soil.

INOCULATION EXPERIMENTS.

The Rheosporangium cultures above referred to, strain 229 furnished by Dr. Edson and strain 351 received from the University of Wisconsin, were tested on pine and red-beet seedlings, with parallel inoculations with *Pythium debaryanum*. The results appear in Table VI.

TABLE VI.—*Results of parallel inoculation with Rheosporangium aphanidermatus and Pythium debaryanum on pine seedlings in autoclaved soil.*

Experiment number, host, and inoculating fungus.[a]	Number of pots.	Results. Emerged (per cent of seed).	Results. Damping-off (per cent).	Results. Survival (per cent of seed).
No. 30, Pinus ponderosa:		*Per pot.*	*Per pot.*	*Per pot.*
Rheosporangium, strain 229	5	23	3	22
Pythium, 2 strains	5	14	38	9
Controls	5	20	22	16
No. 31, Pinus banksiana:				
Rheosporangium, strain 229	5	45	13	40
Pythium, strain 225	10	12	44	7
Controls	25	43	5	41
		Per 5-pot unit.		*Per 5-pot unit.*
No. 58, Pinus banksiana:				
Rheosporangium, strain 229	5	46	2	45
Pythium, 8 strains	40	2.6	50	1.3
Controls	10	78	0	78
No. 59, Pinus banksiana:				
Rheosporangium, strain 229	5	46	11	41
Pythium, 8 strains	40	15	35	10
Controls	10	64	0	64
No. 61, Pinus banksiana:				
Rheosporangium, strain 351	20	16	36	10
Pythium, 2 strains	20	2	57	1
Controls	20	60	2	59
No. 61, Pinus banksiana and beets in same pots:				
Pines } Rheosporangium, strain 351	5	1	([b])	([b])
Beets }		70	88	8
No. 61, beets alone:				
Rheosporangium, strain 351	5	43	72	12
No. 62A, beets:				
Rheosporangium, strain 229	15	89	1	88
Rheosporangium, strain 351	4	42	35	27
Pythium, 2 strains	20	12	83	2
Controls	11	86	0	86
No. 62A, beets:				
Rheosporangium, strain 229	5	50	20	40
Rheosporangium, strain 351	5	[c] 27	78	[c] 6
Controls	5	[c] 77	1	[c] 76
No. 62A, beets and Pinus banksiana in same pots:				
Pines } Rheosporangium, strain 229	5	64	14	55
Beets }		42	22	33
Pines } Rheosporangium, strain 351	5	46	33	31
Beets }		27	78	6
Pines } Controls	5	81	0	81
Beets }		67	0	57
No. 62B, Jack pine:[d]				
Rheosporangium, strain 229	2	58	14	50
Rheosporangium, strain 351	2	53	10	48
Pythium, strain 258	2	10	100	0
Controls	3	82	0	82
No. 66, Jack pine:				
Rheosporangium, strain 229	5	63	9	58
Rheosporangium, strain 351	5	80	52	39
Pythium, 47 strains and substrains	235	43	33	29
Controls	25	75	14	64
No. 67, Jack pine:				
Rheosporangium, strain 229	5	107	0	107
Rheosporangium, strain 351	5	88	6	83
Pythium, 47 strains and substrains	235	51	26	38
Controls	23	87	5	83
No. 68, Red pine:				
Rheosporangium, strain 229	5	105	0	105
Rheosporangium, strain 351	5	124	0	124
Pythium, 47 strains and substrains	235	86	27	63
Controls	18	104	0	104

[a] Location of the inoculum: In experiment 30, at one point at the edge of each pot; in experiment 31, over the entire pot; in all other experiments, over one-quarter the area of each pot.
[b] The breakage of the one seedling not killed while sprouting prevented the determination of results.
[c] Double seed density in these pots; emergence and survival figures halved to allow direct comparison with other units. This high seed density may explain in part the higher loss in strain 351 than in strain 229.
[d] Experiment 62B was conducted at the same time as 62A, but with a different soil.

Table VI shows that in experiments 30 and 67 the loss was less in the Rheosporangium pots than in the controls and that in experiment 68 the results were entirely negative, while in the remaining seven experiments the losses were heavier in the Rheosporangium pots. Especially in experiments 61 and 62A the evidence indicates very strongly that both germination loss and subsequent damping-off of the seedlings which come up can be caused by inoculation with Rheosporangium on jack pine under favorable inoculation conditions. It is, however, obvious that in all of the experiments the parallel inoculations with *Pythium debaryanum* gave much more positive results. The Pythium was active under conditions in which the Rheosporangium gave no evidence whatever of parasitic capacity. It furthermore appears that the two strains of Rheosporangium, though probably identical originally, differed in virulence at the time of their comparison in these experiments. The greater virulence of strain 351 was quite distinct in most of the comparative tests on beets as well as on pines. The possibility that the original culture was really a composite of two or more strains, of which different ones survived in the subcultures kept at Washington and Madison, respectively, seems worth considering. Such an accident might also have been responsible for the divergence of Pythium strains 131 and 295 referred to in another section.

Further evidence of the parasitism of Rheosporangium was obtained in inoculations with cultures reisolated from seedlings killed by the original strains in experiment 62. Typical Rheosporangium, identified by presporangium formation, was easily recovered from the damped-off seedlings in pots of pines only, those of beets only, and the pots in which both hosts were sown. The recovery of a virulent Pythium strain from a single one of the pots inoculated with the weaker Rheosporangium shows that despite the absence of disease in the controls a slight amount of contamination did occur. However, the comparative ease with which the Rheosporangium was isolated from seedlings in other pots inoculated with it and the fact that it has never been obtained in the numerous cultures made from controls and from pots inoculated with other organisms leave little room for doubt that the strains isolated were really recoveries of the Rheosporangium used in the original inoculations. The results of reinoculation with these strains are shown in Table VII.

From Table VII and by comparison with Table VI it appears—

(1) That in one experiment each on jack pine and red pine the reisolated Rheosporangium strains gave positive results. In a second experiment on jack pine (No. 67) the difference between the Rheosporangium pots and the controls was not significant.

(2) That, as in Table VI, the Pythium strains used proved on the whole decidedly more parasitic than the Rheosporangium strains. In experiment 66 this is not shown by the percentage of seedlings damped-off, but is sufficiently evident when the germination loss as well as the subsequent damping-off percentage is considered, the survival being here, as in most other cases in which

either of the groups of pots compared is seriously affected by parasites, the most convenient index of the comparative activity of the fungi used. In such a comparison as that between the Rheosporangium pots and the controls in experiment 68 (Table VII), accidental variations in emergence, of course, overshadow the slight effect of the fungus, and the definitely determinable percentage of loss after emergence is the only value which can serve as a basis for any definite conclusion.

TABLE VII.—*Results of inoculations on pine seedlings with initial and reisolated strains of Rheosporangium aphanidermatus compared with parallel inoculations with Pythium debaryanum.*

Experiment number, host, and inoculating fungus.	Reisolation source.	Number of pots.	Number of strains.	Results.		
				Emerged (per 5-pot unit).	Damping-off (per cent).	Survival (per 5-pot unit).
No. 66, Pinus banksiana:						
Rheosporangium—						
Strain 229	Edson from beet	5	1	63	9	58
Strain 351	do	5	1	80	52	39
Strains 403 and 404	Strain 229 from beet	10	2	78	43	44
Strains 405, 406, and 407	Strain 351 from beet	15	3	63	43	36
Strains 417, 430, and 433	Strain 351 from pine	15	3	72	42	41
Average		50	10	70±2.7	40	42±3.8
Controls		25		75	15	64
Pythium, average		235	47	43	33	29
No. 67, Pinus banksiana:						
Rheosporangium—						
Strain 229	Edson from beet	5	1	107	0	107
Strain 351	do	5	1	88	6	83
Strains 403 and 404	Strain 229 from beet	10	2	91	8	84
Strains 405, 406, and 407	Strain 351 from beet	15	3	92	4	88
Strains 417, 430, and 433	Strain 351 from pine	15	3	83	3	80
Average		50	10	90±2.4	4	86±2.9
Controls		23		87	5	83
Pythium, average		235	47	51	26	38
No. 68, Pinus resinosa:						
Rheosporangium—						
Strain 229	Edson from beet	5	1	105	0	105
Strain 351	do	5	1	124	0	124
Strains 403 and 404	Strain 229 from beet	10	2	102	1	101
Strains 405, 406, and 407	Strain 351 from beet	15	3	105	5	100
Strains 417, 430, and 433	Strain 351 from pine	15	3	100	3	97
Average		50	10	105±2.3	2	102±2.5
Controls		18		104	0	104
Pythium, average		235	47	86	27	63

A frequency graph based on the survivals of the 50 individual pots inoculated with Rheosporangium in experiment 68 yields a rather interesting asymmetrical curve (fig. 17). The shape of the curve is taken as indicating that in a large number of the pots the inoculation produced no effect, while in the smaller number of pots in which the inoculation apparently "took," the loss was rather heavy. This is a rather common phenomenon in inoculations which are only partly successful, part of the pots being free or practically free from loss, while others are nearly cleaned out. It will be seen again in figure 18. This suggests, further, that part of the lack of activity was due to the failure of the fungus to maintain itself vigorously in the soil till the pines reached a stage of sprouting in which they could be readily attacked. Direct inoculations after the seed starts to sprout are therefore desirable to supplement the experiments reported. The survivals in the controls did not show any such asymmetrical distribution.

While the Rheosporangium has given rather definite evidence of parasitism on *Pinus banksiana* under favorable conditions, the activity of the strains available has been much less than that of the *Pythium debaryanum* strains. In view of the fact that the fungus has not so far been isolated from pine it can be concluded to have no general importance in pine seed beds. Its very rapid growth on prune agar makes it very easy to isolate when present.

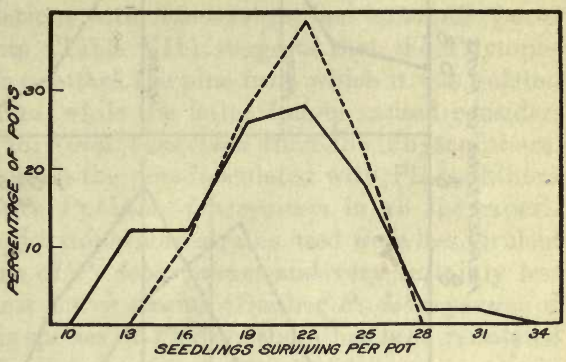


FIG. 17.—Diagram showing the results of inoculation of *Pinus resinosa* seedlings with *Rheosporangium aphanidermatus*, as indicated by the number of seedlings surviving in inoculated pots (solid line) and control pots (broken line). The shape of the curve for the inoculated pots is taken as indicating that a large proportion of them were entirely unaffected by inoculation, while those which were at all affected suffered considerably. This is a frequent result in inoculations with weak parasites added at the time of sowing the seed.

PHYTOPHTHORA SPP.

Phytophthora fagi R. Hartig has been commonly reported as the cause of death of seedlings of various plants in Europe, including conifers and herbaceous plants as well as beech (5, 8, 15, 55, 56, 57, 59, 73, 104.) It has been grouped with the rather indefinite *Phytophthora omnivora* and with *P. cactorum*, the enemy of cactus, ginseng, and other plants. Wilson (147, p. 54) considered it distinct, but Rosenbaum (114), in his biometric comparison of *Phytophthora cactorum* and a single strain of *P. fagi*, failed to find significant morphological differences. If *P. fagi* is even physiologically different from the American strains of *P. cactorum*, its introduction into the United States is to be guarded against. There is certainly no fungus in the United States causing the damage to coniferous seedlings which European reports have attributed to *P. fagi* there. As *P. fagi* attacks roots, it presumably can be carried in soil as well as on plant parts.

A test made on jack pine with a culture of *Phytophthora cactorum*, furnished by the department of plant pathology of Cornell University, resulted negatively. At the time of sowing the seed three pots were inoculated with cultures on nutrient agar inserted at several points in each pot. After emergence additional fragments of prune-agar cultures were placed in contact with the seedlings, and they were

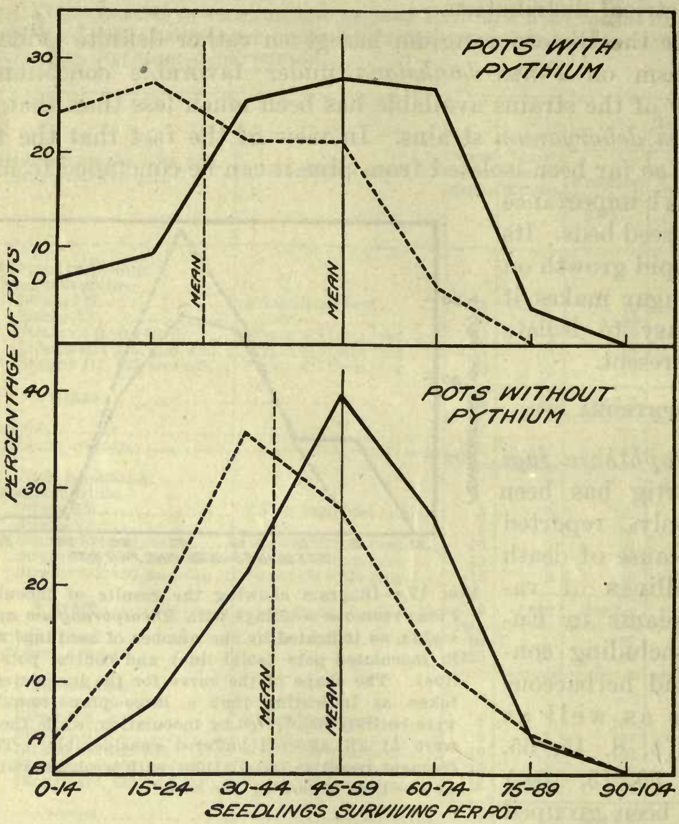


FIG. 18.—Frequency of pots with different numbers of surviving seedlings of *Pinus banksiana*, inoculation experiment No. 31. The solid lines represent pots to which cultures of saprophytic organisms were added. The broken lines are based on pots to which no saprophytes had been added. The solid lines are based on 78 pots in the upper graph and 80 pots in the lower one; the broken lines on 33 pots in the upper and 25 pots in the lower graph. *Pythium debaryanum* was added just after sowing the seed at a single point in each pot represented by the two upper lines. Cultures of saprophytes were applied broadcast two days before the Pythium inoculations were made.

sprayed with a spore suspension. The pots were covered with glass to increase atmospheric moisture, and the seedlings were occasionally sprayed with an atomizer. The soil was an autoclaved mixture in which simultaneous inoculations in a different room with Pythium and Corticium proved successful. The failure of the Phytophthora may possibly have been due to the lower temperature at which the pots inoculated with it were kept (15° to 20° C.).

A species of Phytophthora was isolated by Mr. R. G. Pierce from damped-off *Pinus resinosa* in Minnesota and used in four inoculation experiments, the results of which appear in Table VIII. In the first of these experiments unboiled water was used on the pots, and mice obtained access to the pots of the second test. Probably as a result of these things infection occurred in the controls in both cases, and the results were inconclusive; in the later experiments these two sources of infection were eliminated, and in experiments 68 and 72B the controls were free from disease. Parasitic activity was indicated rather strongly in experiments 68 and 72 (on *P. resinosa* and *P. banksiana*) and to a certain extent in experiment 66. In experiment 67 it was evident that the Phytophthora was nearly or entirely inactive. Comparison of the results in experiments 66 and 68 with the results from inoculations with *Rheosporangium aphanidermatus* in the same experiments (Table VII) suggests that the Phytophthora may be better able to attack the pine from which it was isolated than the Rheosporangium, while the latter fungus caused considerably more destruction to *Pinus banksiana* than the Phytophthora. Comparison of the results in the pots inoculated with Phytophthora and those inoculated with *Pythium debaryanum* in all the experiments indicates that the Phytophthora strains used were less virulent than most of the strains of *P. debaryanum* and very certainly less destructive than the most active strains of either *P. debaryanum* or *Corticium vagum*. This species of Phytophthora has been reisolated from damped-off *Pinus ponderosa* in experiment 72.

Direct inoculations of the stems of seedlings of *Pinus resinosa* soon after they emerge from the soil have so far confirmed the lack of parasitism of *Phytophthora cactorum* and of the cultures of *Phytophthora* sp. grown by the writer. The identity of this species has not yet been determined. It is able to grow only about one-fourth as rapidly as *Pythium debaryanum* on the medium which has been used for isolation and may therefore be more common in the seed beds than the small number of isolations by the planted-plate method would indicate. However, its oospores, larger and darker than those of *Pythium debaryanum* (usually over 20 μ in diameter), should have been recognized in the routine microscopic examination of planted-plate cultures had this species been frequently present, even if it had not grown fast enough to get out ahead of the other organism and allow isolation. It is not believed that it is common enough in pine seed beds to be of importance, even if other strains should be found more virulent than those which have been available.

MISCELLANEOUS PHYCOMYCETES.

A fungus, apparently referable to the somewhat indefinite *Pythium artotrogus* (Mont.) De Bary, was isolated by Mr. Glenn G. Hahn from *Pinus resinosa* in Michigan and from damped-off *Pinus bank-*

siana in pots of autoclaved soil which had received tap water at Washington, D. C. It agreed both in the appearance and measurements of its spiny oogones and smooth oospores with *Pythium artotrogus* (*P. hydnosporus*) as described and figured by Butler (23). In addition to the spores which Butler describes, there appeared in apparently pure prune-agar cultures of different strains bodies with smooth walls, of somewhat irregular ovoid outline, and mostly larger than either oospores or oogones. They are very much less abundant than the sexual spore forms. Their greatest diameter varied from 11 μ to over 40 μ. The germination of these bodies was not observed. Efforts to induce the fungus to produce swarm spores by growing them in liquid nutrient media and transferring them to pure water were unsuccessful. This failure to produce zoospores is further indication of the identity of the fungus with that described by Butler, who says that asexual reproduction is unknown.

The strain from Michigan was a rather weak growing organism, difficult to maintain in tube cultures without rather frequent transfers. Its parasitic activity in the experiments reported in Table VIII is nil or negligible. Because of the poor seed and small number of seedlings involved in experiment 72B, the percentage of damping-off there given means only a single seedling dead. The Washington strains, on the other hand, though evidently not strong parasites, did apparently cause the death of a number of seedlings. The best evidence of this is in experiment 68, in which there was damping-off in each of the five 5-pot units containing the Washington strains and none in any of the 18 control pots. The available strains were less active not only than *Pythium debaryanum*, but less than the Rheosporangium and Phytophthora strains used. The fungus is believed to be a potential parasite on pine seedlings, but not one of any general importance. What is probably the same fungus had appeared in the writer's cultures from western nurseries in conjunction with *P. debaryanum*, but not commonly, and it had not been isolated. While its growth rate is only about half that of *P. debaryanum* on prune agar, it is nevertheless so much faster than that of many fungi that it should have been more often obtained in culture were it at all common in damped-off seedlings.

Another fungus, presumably an oomycete but producing only chlamydospores in the writer's cultures, was obtained from damped-off olive seedlings furnished by Prof. W. T. Horne and from soil direct, both at Berkeley, Calif. The fungus is apparently the same as one which has been occasionally seen in cultures from pine seedlings in the Middle West, but had not before been isolated. The hyphæ are ordinarily nonseptate, and the growth on corn-meal agar is superficially much like that of *Pythium debaryanum*, but with greater tendency toward local zonation and aerial growth and less than half as rapid. Chlamydospores are mostly intercalary, at first subspherical, soon becoming polygonal, and after a few days they shrivel and exhibit thick, angular walls. In size the unshrunken spores usually lie between 8 and 12 μ in diameter, but bodies as large as 20 μ occasionally occur. Antheridia have not been observed, and the shriveled bodies are not believed to be oospores, though the observations made have not been sufficient to exclude such a possibility. No other spore form was obtained in water culture, using various nutrient substrata. In inoculation the strain from olive (the "undetermined Phycomycete" included in Table VIII) has given negative or nearly negative results in three inoculation tests in which other fungi gave positive results. In a test not included in the table, in which *Pinus ponderosa* was the trial host, damping-off was slightly higher in the inoculated pots than in the controls, but the difference was apparently due to accidental infection with Botrytis and *Pythium debaryanum*. As all the seedlings in pots inoculated with *P. debaryanum* in this additional experiment were killed, the relative unimportance of this strain of the small-spored fungus was further indicated. An additional test of both the olive strain and the strain from soil was made by inoculating seedlings of *Pinus banksiana* and *P. ponderosa* growing on filter paper in Petri dishes. Some of these were kept wet with water, some with an inorganic culture solution, and some with the inorganic solution plus peptone and dextrose. Agar cultures were applied directly to the seedlings. The seedlings inoculated with the small-spored fungus remained alive as long as the control seedlings, while parallel inoculations with *Pythium debaryanum* resulted in the early decay of the seedlings.

TABLE VIII.—*Results of inoculations with miscellaneous oomycetes on pines in autoclaved soil at the time of sowing.*

[In all the experiments included in this table, the inoculum consisted of fragments of agar cultures distributed with the seed at one side of each pot over about one-fourth of the pot area. The controls received sterile agar in the same way.]

Experiment number, host, and inoculating fungus.	Number of pots.	Results.		
		Emerged.	Damping-off.	Survival.
No. 66, Pinus banksiana:		*Per 5-pot unit.*	*Percent.*	*Per 5-pot unit.*
Phytophthora sp.—				
Strain 358	5	70	30	49
Strain 372	5	75	28	54
Strain 375	5	94	16	79
Pythium artotrogus (?), Michigan strain	4	115	14	99
Undetermined Phycomycete	5	83	9	76
Controls	25	75	14	64
No. 67, Pinus banksiana:				
Phytophthora sp.—				
Strain 358	5	96	1	95
Strain 372	5	88	3	85
Strain 375	5	99	0	99
Pythium artotrogus (?), Michigan strain	5	102	2	100
Undetermined Phycomycete	5	98	0	98
Controls	23	87	5	83

TABLE VIII.—*Results of inoculations with miscellaneous oomycetes on pines in autoclaved soil at the time of sowing*—Continued.

Experiment number, host, and inoculating fungus.	Number of pots.	Results. Emerged.	Damping-off.	Survival.
No. 68, Pinus resinosa:		*Per 5-pot unit.*	*Per cent.*	*Per 5-pot unit.*
Phytophthora sp.—				
Strain 358	5	104	7	97
Strain 372	5	109	18	89
Strain 375	5	98	5	93
Pythium artotrogus (?), Michigan strain	5	121	0	121
Pythium artotrogus (?), Washington, D. C.—				
Strain 821	5	122	1	121
Strain 823	5	120	9	109
Strain 831	5	96	5	91
Strain 832	5	110	6	103
Strain 833	5	94	1	93
Undetermined Phycomycete	5	84	2	82
Controls	18	104	0	104
No. 72A, Pinus resinosa:		*Per 3-pot unit.*		*Per 3-pot unit.*
Phytophthora sp.—				
Strain 372	3	20	35	13
Pythium artotrogus (?), Michigan strain	3	62	0	62
Pythium artotrogus (?), Washington, D. C.—				
Strain 821	2	45	7	42
Strain 831	3	37	0	37
Strain 833	3	40	25	30
Controls	16	35	5	33
No. 72B, Pinus ponderosa:				
Phytophthora sp	3	8	50	4
Pythium artotrogus (?), Michigan strain	3	13	8	12
Pythium artotrogus (?), Washington, D. C.—				
Strain 821	3	11	0	11
Strain 831	2	29	6	27
Strain 833	2	6	0	6
Controls	14	9	0	9

OTHER FUNGI.

Data on the possible relation between various other fungi and the damping-off of conifers have been already summarized by Hartley, Merrill, and Rhoads (68, p. 546–550). *Pestalozzia funerea* on the basis of the experiments of Spaulding (135), *Botrytis cinerea* on the basis of observation and very preliminary inoculations, and *Trichoderma koningi* on cultural evidence only are all believed to be potential causes of damping-off, though not ordinarily important. *Alternaria* sp. is under a certain amount of suspicion on account of its frequent association with the damping-off of conifers, but it has never been used in experiments. *Rhizopus nigricans* (incorrectly reported as Mucor), *Trichothecium roseum*, *Rosellinia* sp. from nursery soil, *Chaetomium* sp. from maple roots, strains of Penicillium and Aspergillus, *Phoma betae*, and *Phoma* spp. are all reported to have been used in inoculations with negative results.

Since the publication of the above summary a preliminary successful inoculation experiment with *Botrytis cinerea* on recently emerged *Pseudotsuga taxifolia* has been found briefly mentioned in an article by Tubeuf (140) on another disease. Further experiments with various strains of Botrytis, both from conifers and from other hosts (the latter supplied by the departments of plant pathology of the California and New York (Cornell) Agricultural Experiment Stations), have already yielded confirmatory evidence of the parasitism of *B. cinerea.*

While a considerable number of fungi have been considered in the foregoing, it is entirely possible that there are still parasites which have received no consideration and that some of them may perhaps be important. The moist-chamber method of culturing parasites for isolation yields only those which produce spores readily; the planted-plate method is not well adapted to the isolation of slow-growing fungi or bacteria. It is suggested that in further culture work with damped-off conifers an attempt be made to secure slow-growing organisms by dilution plates of teased-up fragments of recent lesions.

RELATIVE IMPORTANCE OF THE DAMPING-OFF FUNGI ON CONIFERS.

The relative importance of the different damping-off parasites is something that has not been thoroughly investigated for any host. The most information on this point is that given by Busse, Peters, and Ulrich (22) for sugar beet. In this case they find the specialized *Phoma betae* distinctly the most important, with *Pythium debaryanum* second and *Aphanomyces levis* third.

Peters (100) apparently considered Rhizoctonia unimportant as a cause of beet damping-off. The opposite was indicated by a small number of cultures by Edson (38) from beet seedlings on Kansas and Colorado soil. These yielded more *Corticium vagum* than any other parasite and no Pythium at all. Johnson (81) states that most of the damping-off of tobacco seedlings is due to *Pythium debaryanum* and *Corticium vagum.* Atkinson (1), speaking for cotton in Alabama, and Sherbakoff (127, p. xcv; 128; 129), speaking for truck crops in Florida, make *Corticium vagum* the important damping-off parasite, with *P. debaryanum* negligible. Horne (oral communication) found the same situation in tobacco seed beds in Cuba. Atkinson (3), in an article on trees, held that many of the cases of damping-off attributed to *P. debaryanum* are in reality due to *C. vagum.* Peltier (98, pp. 336–337) has reported *Rhizoctonia solani* as the cause of damping-off of a large number of plants, recording his observation of the damping-off of seedlings of nearly 50 species of miscellaneous genera and cuttings of 13 different species, all of which he attributes to the Rhizoctonia. He does not state whether in this case he used diagnostic methods likely to detect *Pythium debaryanum* if it had been present.

For the conifers, no very reliable data on relative importance have been published. Numerous European reports emphasize the damage due to *Fusarium* spp., while a smaller number attribute loss to *Phytophthora fagi* or to both. There seems to have been little effort to determine the presence or absence of Corticium or Pythium, so these reports can not be given great weight. Spaulding's evident belief (136) in the importance of Fusarium has more weight, as he was on the lookout for the other fungi; the moist-chamber diagnostic method employed in most of this work was, however, not well adapted to the detection of either one. The same is true of the work of Rathbun (106), in which dilution plates of seed-bed soil were employed. Rankin (105) attributes to *Fusarium* spp. the greatest importance in tree seed beds in this country, with *Pythium debaryanum* and *Rhizoctonia* spp. important in certain cases. Gifford (46) emphasizes the importance of Fusarium, while Clinton (28) apparently found Rhizoctonia (*Corticium vagum*) especially prevalent in the examinations he made.

On the basis of the data presented or summarized in this bulletin, it is believed that of the various organisms which have been connected with damping-off in coniferous seed beds *Pythium debaryanum*, *Corticium vagum*, and *Fusarium* spp. include all of importance. The others, either because of low indicated virulence or infrequent occurrence, and in most cases both, do not seem to merit extensive consideration.

In order to form an idea of the relative frequency of the parasites named above as important, there have been brought together in Table IX the results of the examination of 438 damping-off foci in untreated beds and 304 foci which have appeared in beds which had received various disinfectant treatments. The data are presented by foci rather than by individual seedlings, as was done in the census reported by Busse and his coworkers. Most of the diagnoses were made by planting recently diseased seedlings in plates of solidified prune agar, all the seedlings taken from the same focus, or "patch," of damped-off seedlings being put into the same Petri dish. The resulting growth was in some cases transferred to a tube for later examination, but was usually examined directly in the plate. In a smaller number of foci the seedlings were macerated and examined directly without recourse to culture methods. As *Pythium debaryanum* does not commonly fruit in diseased seedlings of pine or of tobacco (81) and its hyphæ are both difficult to find and not in themselves considered a sufficient diagnostic character, this latter method of examination is not so satisfactory for the determination of Pythium as it is for Corticium, which is easily recognized by its thick-walled truncate-tipped hyphæ and characteristic branching. A further difficulty in the direct-examination method, unless the seedlings are sectioned, is in distinguishing between Corticium hyphæ which are in the tissues and those outside. The well-known habit of the Corticium of sending hyphæ superficially over the surface of plants which it is not appreciably injuring makes it evident that only hyphæ actually found in the tissues have diagnostic value. Direct microscopic examination is, furthermore, very likely to fail to detect Fusarium. The planted-plate method therefore appears the better of the two, and the results of the culture diagnoses appearing in the lowest two lines of Table IX deserve probably more attention than the total occurring a few lines above, in which the results of direct examination of the seedlings are also included. The high proportion of Corticium reported from the Michigan and Minnesota nurseries is probably due in part to the fact that most of the examinations made there were of the direct microscopic type.

TABLE IX.—*Results of the examination of damping-off foci in coniferous seed beds for Pythium debaryanum, Corticium vagum, and Fusarium spp.*

Grouping.	Untreated beds.				Beds of heated soil.				Beds treated with strong acids.			
	Foci examined.	Number showing—			Foci examined.	Number showing—			Foci examined.	Number showing—		
		Pythium.	Corticium.	Fusarium.		Pythium.	Corticium.	Fusarium.		Pythium.	Corticium.	Fusarium.
By locality:												
Berkeley, Calif.	4	3	1	2	....	....	....	....	5	5	0	2
Manitou, Colo.	22	0	19	0	....	....	....	....	....	....	....	....
Monument, Colo.	34	6	20	13	....	....	....	....	....	....	....	....
Garden City, Kans.—												
Garden City Nurseries	18	4	0	9	14	5	0	7	28	8	2	9
Kansas Nurseries (sand)	20	4	9	7	15	2	0	6	16	9	2	8
Halsey, Nebr.	224	124	45	155	28	10	0	17	99	34	2	61
Cass Lake, Minn.	42	15	21	5	....	....	....	....	1	0	0	0
Dundee, Ill.	4	0	4	1	....	....	....	....	....	....	....	....
East Tawas, Mich.—												
Beal Nurseries (sand)	45	14	33	2	....	....	....	....	1	1	0	0
East Tawas Nurseries	13	11	7	1	....	....	....	....	13	7	6	2
Washington greenhouse	12	3	3	9	7	2	0	3	....	....	....	....
Total:												
Number	438	184	162	204	64	19	0	33	163	64	12	82
Percentage	100	42	37	47	100	30	0	52	100	39	5	50
By diagnostic methods:												
Direct examination—												
Number	156	39	108	25	0	....	....	....	16	6	8	4
Percentage	100	25	69	16	....	....	....	....	100	38	50	25
Planted-plate cultures—												
Number	282	145	54	179	64	19	0	33	147	58	4	78
Percentage	100	51	19	63	100	30	0	52	100	39	3	53

TABLE IX.—*Results of the examination of damping-off foci in coniferous seed beds for Pythium debaryanum, Corticium vagum, and Fusarium spp.*—Con.

Grouping.	Beds treated with formaldehyde.				Beds treated with copper sulphate.				Beds treated with zinc chlorid.				All treated beds.			
	Foci examined.	Number showing—			Foci examined.	Number showing—			Foci examined.	Number showing—			Foci examined.	Number showing—		
		Pythium.	Corticium.	Fusarium.		Pythium.	Corticium.	Fusarium.		Pythium.	Corticium.	Fusarium.		Pythium.	Corticium.	Fusarium.
By locality:																
Berkeley, Calif.	.....	....	....	....	.....	....	....	....	.....	....	....	....	5	5	0	2
Manitou, Colo.	.....	....	....	....	.....	....	....	....	.....	....	....	....	.....	....	....	....
Monument, Colo.	.....	....	....	....	.....	....	....	....	.....	....	....	....	.....	....	....	....
Garden City, Kans.—																
Garden City Nurseries	6	0	6	3	1	0	0	1	3	1	0	3	52	14	8	23
Kansas Nurseries (sand)	.....	....	....	....	.....	....	....	....	.....	....	....	....	31	11	2	14
Halsey, Nebr.	34	20	1	24	6	3	0	5	8	0	0	5	175	67	3	112
Cass Lake, Minn.	.....	....	....	....	.....	....	....	....	.....	....	....	....	1	0	0	0
Dundee, Ill.	.....	....	....	....	.....	....	....	....	.....	....	....	....	.....	....	....	....
East Tawas, Mich.—																
Beal Nurseries (sand)	.....	....	....	....	.....	....	....	....	.....	....	....	....	1	1	0	0
East Tawas Nurseries	8	5	4	0	6	5	3	3	5	3	0	2	32	20	13	7
Washington greenhouse	.....	....	....	....	.....	....	....	....	.....	....	....	....	7	2	0	3
Total:																
Number	48	25	11	27	13	8	3	9	16	4	0	10	304	120	26	161
Percentage	100	52	23	56	100	62	23	69	100	25	0	63	100	39	9	53
By diagnostic methods:																
Direct examination—																
Number	8	5	4	0	5	4	2	2	5	3	0	2	34	18	14	8
Percentage	100	63	50	0	100	80	40	40	100	60	0	40	100	53	41	24
Planted-plate cultures—																
Number	40	20	7	27	8	4	1	7	11	1	0	8	270	102	12	153
Percentage	100	50	18	68	100	50	13	88	100	9	0	73	100	38	4	57

The data on the different nurseries do not allow any generalizing on the basis of locality except to say that all of the fungi seem quite generally distributed in the Lake States and Great Plains region. In general, it appears that the Fusaria as a group are more common than either of the other fungi; as they grow more slowly than either the Pythium or the Corticium, they were probably rather more common relatively than even the plate-culture method indicated. It also appears that the Pythium occurred in more foci than the Corticium in the beds examined. Further culture work, perhaps by the method of dilution plates of fragments of lesions, seems desirable, especially in the East and the Northwest, regions in which there are large coniferous nurseries and in which nothing like a parasite census has been attempted. Observations on the type of focus occurring in most of the nurseries in the Rocky Mountains leads the writer to believe that Corticium will be found especially important there.

While the data on the fungi in foci in disinfected beds are insufficient to serve as a basis for much in the way of conclusions for any individual treatment, they in general agree with the assumption, which knowledge of the fungi would favor, that Corticium is the most easily controlled by soil disinfection (see the bottom line in the last four columns of Table IX). Its poor adaptation for aerial dissemination would lead one to expect to find it seldom in beds treated with efficient disinfectants. The entire absence of Corticium in heated soil therefore seems somewhat significant. The rather high Corticium yield in the formaldehyde plats is of some interest in view of the reported inefficiency of formaldehyde in destroying *Corticium vagum* on potato tubers (48, 50). As will be noted from the data given, more than one suspected parasite was often found in what appeared to be a single focus. This was probably in some cases due to independent foci being nearly concentric; it also in some cases undoubtedly means that one of the organisms found was only secondary. In the beet-seedling cultures by Busse and his associates, individual seedlings yielded two or more potential parasites in 100 of their nearly 1,300 examinations. It not infrequently happened in the work on pine seedlings that no fungus recognized as a likely parasite could be isolated. This was especially true in plate cultures when Rhizopus or Trichoderma happened to be abundant, as both are very fast growing and often suppress parasites. This is an additional reason for the development of some method as a dilution plate of lesion fragments for diagnosing damping-off.

Even an accurate and complete census of the organisms present in the different foci could not be directly interpreted in terms of relative importance. None of the parasites so far used in inoculation have been vigorously parasitic under all conditions. Of both *Corticium vagum* and *Pythium debaryanum* some strains, microscopically indistinguishable from the others, are very weak as parasites. Only part of the Fusarium species are parasitic on pine, and data showing which are and which are not parasitic are known for only a very few. There is therefore no fungus which can be said positively to be the cause of any particular damping-off "patch" simply because it was found in some of the dead seedlings in the patch. In an occasional exceptional case, such as the large Corticium patch in figures 7 and 8, there is such a vigorous growth of the fungus that its predominance is undoubted, but such cases are rather rare. A census throws light on the importance of the different fungi, but can be interpreted only in the light of inoculation results.

For Pythium and Corticium the inoculation data do not permit any simple comparison between the two, for the reason that neither is uniform. Each has strains of high virulence and strains having practically no effect on pines. In the inoculations in autoclaved soil at sowing time the strongest strains of *Corticium vagum* have on the whole caused more damage than any of the Pythium strains, but, on the other hand, there has seemed to be a higher proportion of very weak strains of *C. vagum* than in the case of Pythium. In inoculations on *Pinus banksiana* and *P. ponderosa* in Kansas sand treated with acid followed by lime, the average Corticium was very much more destructive than even the strongest Pythium strains, allowing practically no germination in most cases. On the other hand, in experiments in which the inoculum was applied directly to *Pinus resinosa* and *P. ponderosa* seedlings, either immediately after germination or after the older parts had become resistant, the Pythium has been the more effective. The inoculation evidence so far available justifies so nearly equal emphasis on the two that it can practically be eliminated from the calculations. It is the writer's opinion that the Corticium strains are probably rather less virulent on the average than the Pythium strains, but perhaps better able to maintain themselves and spread from one seedling to another in most soils. The evidence of Table IX that the Corticium seemed less frequent in the damping-off foci is more or less counterbalanced by the apparent larger size of many of the disease patches which it seems to cause in the seed beds. Nearly all the large clean areas such as are shown in figures 7 and 8 have been found to contain abundant Corticium hyphæ. The evidence on the whole seems to indicate a very nearly equal importance for the two fungi. The Pythium is probably somewhat the more important for the stations at which most of the cultures in Table IX were made, but the Corticium has received more emphasis from other observers in this country and is indicated by the writer's observations to be more important in the western mountains than any other damping-off fungus.

The inoculation evidence for *Fusarium* spp., though less complete than for Corticium and Pythium, is nevertheless rather helpful in indicating their importance rating. None of those so far tested in inoculations at sowing have shown the destructiveness of the average strains of Pythium or of the stronger strains of Corticium; while this is only in part a test of virulence and in part a test of the ability of the fungus to grow saprophytically in the soils used, the indication is that no one Fusarium species is the equal in destructive capacity of either *Corticium vagum* or *Pythium debaryanum*. However, when all of the Fusarium species which occur in the seed beds are considered, the group as a whole may prove quite as important or even more important than either of the other two fungi. The data already at hand rather definitely indicate considerable importance for all three.

DAMPING-OFF FUNGI AS CAUSES OF ROOT-ROT AND LATE DAMPING-OFF.

As has been already stated, root-rot, often with frequent recovery, has been commonly observed in seedlings several weeks old. It has been especially common in the vicinity of old damping-off foci in which *Corticium vagum* appeared to be the active parasite, but beyond this indication of the causal relation of *C. vagum* it was not known which of the damping-off fungi were able to attack the roots of seedlings too old to be killed by damping-off. To throw light on this point, seedlings of *Pinus ponderosa* and *P. resinosa* grown in autoclaved soil in the greenhouse and approximately 1½ months old were inoculated with different fungi. There had been a certain degree of early damping-off in these pots, but it had apparently ceased before the inoculations were made. The inoculum used consisted of cultures on rice introduced through the drainage holes at the bottoms of the pots. The strains of *Pythium debaryanum* and *Corticium vagum* used were the ones which had given maximum results in earlier inoculation experiments at the time of sowing. The strain of *Fusarium ventricosum* was the only one available, and the *Fusarium moniliforme* strains were all of approximately equal virulence, the three used having given as much evidence of parasitism as any of the strains of this species in the earlier damping-off experiments. Three pots of each pine were inoculated with each strain. Two 3-pot units of each pine were set aside as controls and inoculated with sterile rice. In addition, three pots of each pine were kept in the same bench without the addition of any inoculum, for comparison with the controls with rice. The results of this experiment, taken a month after the inoculations were made, with the seedlings averaging 2½ months old, appear in Table X. The roots of the living seedlings were washed out carefully with water to permit examination.

The results in so far as they indicate root-rot of the oldest seedlings are best shown by the figures in columns 4 and 5. These seedlings were so far advanced that the fungi had not been able to kill them, and nearly all would probably have recovered if they had not been dug up. It will be noted from column 4 of Table X that a considerable portion of the *Pinus ponderosa* seedlings with root-rot had already made their recovery apparent by pushing out adventitious roots above the decayed portion at the time they were examined.

For *Fusarium ventricosum* there was only the merest indication of ability to attack pine roots at this stage. For *F. moniliforme* the evidence is somewhat better, more pots being included and the difference in healthy-topped seedlings with injured roots between the inoculated pots and the controls being approximately twice its indicated probable error for each species. The percentage of root-injured seedlings in the *Pythium debaryanum* pots exceeded that in the controls in each species by between three and four times the probable error of the difference, while the difference in percentage between the *Corticium vagum* pots and the controls is approximately four times its probable error in the case of *Pinus ponderosa* and five and one-half times its probable error in the *Pinus resinosa* pots. The weak point in the results is, of course, the insufficiency of the 6-pot and 9-pot groups as bases for probable-error determination. The indicated relative ability of these different fungi to cause root-rot is about the same as their relative ability to cause the damping-off of sprouting seed and young seedlings, as indicated by the results of the earlier experiments in which inoculations were made at the time of sowing. The fact that only the very strongest available strains were used and that the pots were rather heavily inoculated is to be kept in mind in considering these results. As in the seedlings examined in the nursery beds, when a root system was partly rotted it was only the younger portions of the roots that were affected. The evidence obtained from this experiment needs to be amplified by experiments with other coniferous hosts, other strains of the fungi, and under other conditions. The experiment just described furnishes the only evidence available on the relation of the important fungi *Pythium debaryanum* and *Corticium vagum* to the root-rot of conifers and is therefore presented as a preliminary contribution.

TABLE X.—*Results of root inoculations of older pine seedlings with damping-off fungi.*

Host and inoculating fungus.	Number of—		Seedlings which developed root-rot (per cent).				
			Tops still healthy.				
			Root recovery.				
	Pots.	Seedlings.	Started.	Not started.	Average of individual pots.	Killed.	Total.
1	2	3	4	5	6	7	8
Pinus ponderosa:							
Pythium debaryanum, strains 295, 550, and 810.[a]	9	71	27	25	53±4.5	4	56
Corticium vagum, strains 147, 213, and 747.[a]	9	56	16	34	51±3.5	4	54
Fusarium moniliforme, strains 249, 251, and 260.[b]	9	64	19	27	42±6.2	0	45
Fusarium ventricosum	3	18	17	39	50	0	56
Controls	6	41	2	15	22±6.5	0	17
Controls without rice	3	18	0	17	23	0	17
Pinus resinosa:							
Pythium debaryanum	9	140	3	16	18±4.0	12	31
Corticium vagum	9	146	3	16	21±2.4	13	33
Fusarium moniliforme	8	128	0	11	12±3.7	2	13
Fusarium ventricosum	3	39	0	5	4	0	5
Controls	6	115	0	3	4±2.0	6	10
Controls without rice	3	51	0	0	0	2	2

[a] For relative virulence of these strains on younger seedlings as compared with other strains of the same species, note their position in figures 11 and 14.
[b] For performance of these strains in inoculations at time of sowing, see an earlier publication (68, table 2).

The figures in column 7 give information as to the percentage of late damping-off resulting from the inoculations. A certain percentage of the early type of damping-off appeared in some of the pots, as there were still present a number of soft-stemmed seedlings from seeds which were slow in germinating. These younger seedlings were excluded in counting the dead, the rule being to include only plants which had developed a sufficiently rigid stem to remain upright after death. Comparison of the percentage of killed with the total percentage attacked for the two pines is rather interesting. As has already been pointed out, while *Pinus resinosa* suffers very heavy damping-off losses at a number of nurseries it seems to be less susceptible than some other species to parasitic injury during the sprouting period, before the seedlings appear above the soil surface. Observation of beds of this species during different seasons has indicated that it has not a greater susceptibility, but rather the fact that its susceptibility lasts longer, which causes it to suffer as seriously as it does at certain nurseries. It is indicated in Table X that the succulent root tips of *Pinus ponderosa* are just as easily attacked by damping-off parasites as those of *P. resinosa*—in fact, considerably more easily attacked, as indicated by the figures in column 8. With the *P. ponderosa* seedlings, however, the older parts of the roots had become resistant at this age in nearly all cases, while of the affected *P. resinosa* seedlings more than one-third were still unable to limit the lesions, and death resulted.

In general, this experiment indicates that *Corticium vagum* and *Pythium debaryanum* are able to cause the death of some pine seedlings which have developed rigid stems and that both are also able, as has been found by other workers in the case of sugar beets, to cause "root sickness," the rot of the younger portions of the root systems, in seedlings which have developed too much resistance to be killed. The evidence for the parasitism of the two Fusarium species on these older root systems is not so good; as in the experiments on younger seedlings, their ability to attack the pines is probably less than that of the other two fungi. Further inoculation experiments are desirable both with these fungi and with others on the roots of seedlings too old to succumb to the more ordinary types of damping-off.

RELATION OF ENVIRONMENTAL FACTORS TO DAMPING-OFF.

In the earlier section dealing with disease control, mention was made of the general belief on the part of men who have had experience with seedling diseases that damping-off is favored by thick seeding, by much organic matter, especially by poorly rotted manure in the soil, and by excessive moisture in the air and soil. It is also commonly stated that high temperature favors the disease; on this point there is perhaps a less general agreement. Practically all the evidence on these points is observational.

DENSITY OF SOWING.

The relation between the disease and thick sowing was strikingly indicated for tobacco seedlings in a single experiment by Johnson (82). For pines the only available information is from four experiments on *Pinus banksiana.* The results of the first two appear in figure 19. In both experiments there is an indication of an increase in the percentage of diseased plants as the seed density is increased. There is, however, no such marked relation as in Johnson's work. As the pines were sown in drills, they were so close together even in the less dense plats that no very great increase in the ease of spread of the disease was to be expected from increasing the density. Greater differences should be expected in broadcast beds. That heavier losses have been found in drill-sown beds than in those sown broadcast (69, 139) is presumably explained by the fact that with equal numbers of seed per square foot of seed bed the seedlings are much closer together in drills than in broadcast beds, and thus the spread of the mycelium of parasites from one seedling to another is facilitated.

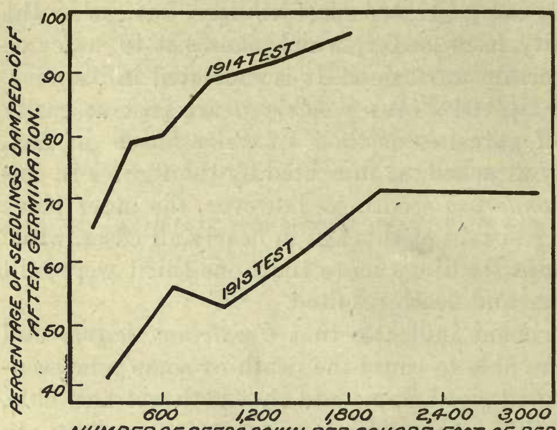


FIG. 19.—Diagram showing the extent of damping-off in drill-sown *Pinus banksiana* in plats with different seed densities. The regular seed density at this nursery was 600 seeds per square foot.

Two tests of different seed densities were also made in 3-inch pots of autoclaved soil in the greenhouse. Each regular pot was sown with 28 seeds (equivalent to 600 per square foot). The pots were inoculated by adding to each a single small fragment of an agar culture of *Pythium debaryanum.* Uninoculated pots showed an emergence of approximately 50 per cent of the seed and were entirely free from subsequent damping-off in both experiments. The results appear in Table XI.

In this case not only the damping-off after emergence but the loss before the seedlings appeared bore an apparent relation to sowing density. In the field experiments there was no evidence that the loss before the seedlings appeared was affected by seed density.

TABLE XI.—*Results of inoculation, at the time of sowing, with Pythium debaryanum on Pinus banksiana in different sowing densities in pots of autoclaved soil.*

[The percentages of "Damping-off," columns 4 and 7, are based on the number of seedlings; the percentages given in columns 3, 5, 6, and 8 are based on the number of seeds.]

Density of seed sowing.	Number of pots in experiment.	Results (per cent).					
		Experiment 58.			Experiment 59.		
		Emerged.	Damping-off.	Survival.	Emerged.	Damping-off.	Survival.
1	2	3	4	5	6	7	8
Regular	10	15	43	10	26	13	23
Double	5	8	65	3	8	91	1
Triple	5	1	100	0	11	34	7
Regular, but 10 additional seeds near point of inoculation	5	6	33	4	17	37	11

MOISTURE AND TEMPERATURE FACTORS.

The relation of damping-off to moisture and temperature are subjects less easily studied. In 1907 and 1908 Mr. W. H. Mast, then supervisor of the Nebraska National Forest, conducted daily counts of the number of seedlings damped-off and compared these records with temperature and rainfall records. The writer in 1909 repeated his work, maintaining parallel records of damping-off, air and soil temperatures, soil moisture, atmospheric humidity, wind movements, and evaporation. The 1909 records of damping-off, temperature, soil moisture, and evaporation appear in figure 20. The damped-off seedlings were counted and removed in the morning and evening, the day period thus being in most cases 10 to 11 hours and the night period 13 to 14 hours. Because the period was not always the same length, the data are reduced to a per hour basis. Air temperature was recorded by a sheltered thermograph 3 feet above the soil surface. The evaporation graph represents the mean loss per hour from two porous cup atometers of the writer's own design, in which the rather long and slender Chamberlain filter bougie was used and supported in a horizontal position just above the soil surface so as to be under as nearly as possible the same atmospheric conditions as the seedlings. The two bougies were placed at right angles to each other in order to eliminate as far as possible the effect of change of wind direction on their mean loss. While the rain-correction mounting had not at that time come into use, the error due to rain absorption appeared negligible; atometers filled shortly before rainfall were read immediately after without any gain being found in the water in the reservoir. The psychrograph and wind-movement records are not presented, as the evaporation values are more easily interpreted. Soil moisture was periodically determined in the soil of the

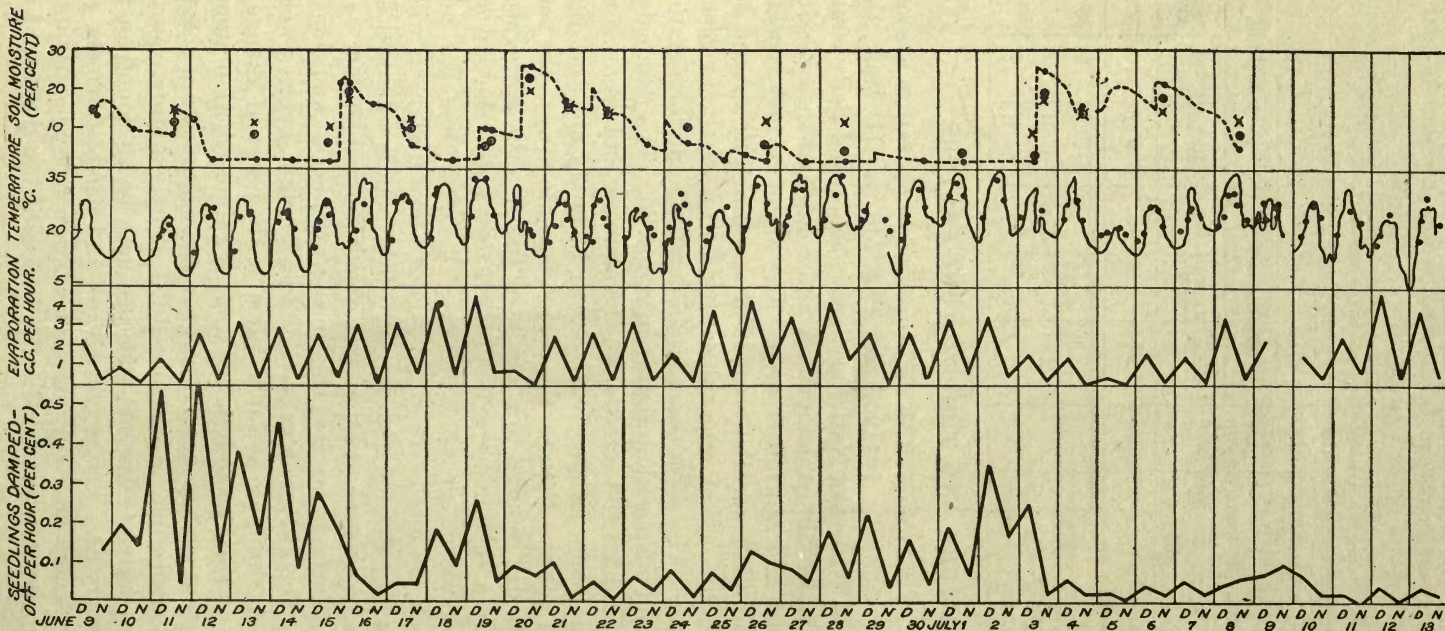


FIG. 20.—Diagram showing the progress of damping-off in beds of *Pinus banksiana* at a nursery in Nebraska and indicating the moisture and temperature conditions. The evaporation from porous-cup atmometers was measured and the dead seedlings counted, night and morning. As the day (D) and night (N) periods into which the time was thus divided were not of equal length, these figures are converted into an hourly basis. The temperature curve is taken from a sheltered thermograph 1 meter above the surface of the beds, while the dots accompanying this curve indicate readings of a thermometer whose bulb was buried 3 cm. below the soil surface. For the temperature and soil-moisture records, the vertical lines indicate 6.00 a. m. Explanation of symbols referring to soil moisture: ● = At depth of 0 to 0.6 cm., ⊙ = at depth of 0 to 2.5 cm., × = at depth of 2.5 to 5 cm.

plats on which the seedling counts were conducted, each determination representing two, and in some cases four, points. The determinations for the upper one-fourth inch of soil, made more frequently than for lower levels, are connected in figure 20 by a dotted line, which gives some idea of the amount of moisture in the surface soil during the periods between determinations. The determinations were too infrequent to permit anything more than an estimate of the moisture conditions between determinations, but the writer, having before him the records of the times and amounts of rainfall and artificial watering as well as the evaporation and soil-moisture determinations, is in a better position to make such an estimate than the reader. The dotted line which gives this estimate should not be depended on to show what the percentage of moisture was at any one time, but is believed reasonably reliable as showing whether in general the soil was wet or dry. In interpreting the soil-moisture records, it should be kept in mind that the soil was very sandy, the wilting coefficient of composite samples from various parts of the nursery, as determined by the indirect method of Briggs and Shantz in the Laboratory of Biophysical Investigations of the Bureau of Plant Industry, being only 3.4 per cent. The hygroscopic moisture in dry air for the soil of the plats actually under consideration was indicated by repeated determinations for the surface soil on dry days to be in the neighborhood of or slightly below 2 per cent. The nursery is located in a region of large temperature fluctuations, where the air during the day is generally dry, and consequently the dew is heavy at night.

The first result of interest is the difference between the damping-off for the day and the night periods. In the records of every day but two, more seedlings went down during the day period than during the night, the differences in most cases being large. As the evaporation and temperature showed similar day and night fluctuations, it is difficult to say whether temperature or moisture conditions were responsible. The other interesting result brought out by the graphs is the sudden drop in the general level of the damping-off graph following the rains of June 15, June 19–20, and July 3. In each of these three cases the damping-off came up again only after the soil moisture came down.

The fact that in the daily fluctuations the damping-off varied directly with the evaporation rather than inversely is an apparent contradiction of the generally accepted doctrine that moisture favors the disease. This contradiction is, however, only apparent. During the first part of the damping-off period, when the seedlings are still soft, the recognition of damping-off depends on the decay of that part of the stem just above the soil surface which allows the seedling to fall over. This usually takes place at this nursery as a result of the extension upward of lesions which have started on the parts a little below the soil surface. It is supposed that such decay takes place most rapidly at high temperatures and that it is the temperature rather than the evaporation graph which the damping-off is following in these early day and night fluctuations. During the latter part of the damping-off period a dying seedling shows its first signs of distress in the drying up of its leaves, the stem being too stiff to go down until after the infection has gone far enough in the roots to cut off most of the water supply. It is, of course, under dry conditions that such a sign of distress will be most in evidence. During the latter part of the damping-off period it is therefore altogether likely that the day and night fluctuations are caused, at least in part, by the higher evaporation rate which obtains during the day. This is a relation not to the rate of progress of the disease, but rather *to the rate at which the symptoms of disease appear in plants already seriously affected.*

The drop in damping-off following the increased soil moisture of June 15, 19–20, and July 3 also apparently contradicts established doctrine. While it is ordinarily true that a wet soil is a cold soil and that in the rainy weather which causes wet soil the evaporation is usually low, it does not seem possible on inspection of the graphs for these items to attribute entirely the reduction of damping-off during these periods of wet soil either to low temperature or to low evaporating power of the air. Lowered soil temperature probably had something to do with the reduced loss following the rains. It is also suggested that a sudden change in moisture content may temporarily hinder a soil fungus by decreasing its air supply. In this sandy soil the fungi can work at very considerable depths during dry periods. Initial lesions have been found as much as 12 inches below the surface. If this soil is as completely changed in its aeration qualities by wetting as the sandy soil with which Buckingham (19) worked, a rain might result in a rather sudden change in the level at which the fungus is able to operate.

On the whole, the graphs tend to confirm the common statement that high temperature favors damping-off. It must, however, be borne in mind that in uncontrolled field plats several factors vary simultaneously, and it is impossible to definitely attribute any observed phenomenon to any one of them. Furthermore, it is not possible to say for the seedlings at different ages just how long it will take a factor to exert an effect on the damping-off curve. An additional consideration is that a method of investigation which gives entirely reliable information on the speed with which the disease develops does not necessarily throw light on the conditions under which the greatest total amount of disease can be expected before the seedlings become old enough to resist attack. High temperatures, within reasonable limits, are expected to increase the speed with which the disease works, but these should also hasten the development of the host to a point at which infections are unable to cause death. It is the total amount of damage in the beds rather than the damage per unit of time which is of practical importance. For a number of reasons, then, the method followed in obtaining the data for these graphs can not give information of maximum value. While data of the sort mentioned are of undoubted interest and would be of still more value if the records had been commenced when the first seedlings appeared instead of a few days later, the relation of any specific factor to the total extent of the disease can be better determined by comparing plats in series in which the factors are as far as possible controlled and varied one at a time. To vary soil moisture and soil temperature independently will prove somewhat difficult, but it can be done with the proper facilities. Some work with environmental factors should be done under conditions of artificial inoculation in the greenhouse, in which the different damping-off parasites can be experimented with separately, as it is obvious that the factors which favor the activity of one may not be favorable for another.

CHEMICAL FACTORS.

Chemical factors are presumably also important, as the soil is in most cases the culture medium for both the parasite and the host. The much greater activity of *Pythium debaryanum* in autoclaved soil than in untreated soil may be due to the larger quantity of soluble organic matter commonly present in autoclaved soil. *Pythium debaryanum* has been found more sensitive to unfavorable substrata in artificial culture than *Corticium vagum* and is apparently more dependent on soil organic matter in the nurseries than is *C. vagum*. For example, in the normal humus-containing surface sand in the beds at Cass Lake, Minn., both Pythium and Corticium occurred frequently in the damped-off seedlings, while in beds a few feet distant, from which enough of the surface soil had been removed to leave no humus, nearly all the damping-off foci contained abundant Corticium, and no Pythium could be found. With both fungi and, in addition, with two species of Fusarium (68) heavy inoculation has been more successful in experiments at the time of sowing than light inoculation. This has been thought possibly due in part to the larger amount of nutrient substratum added in the heavy inoculations, allowing better saprophytic development of the fungus in the soil. In each of the two experiments with Pythium reported in Table XI, a 5-pot unit was treated with corn-meal infusion and another with prune infusion at the time of inoculation. In both experiments germination was lower, damping-off after germination higher, and the survival less than half as great in the pots with infusion as in the inoculated pots not so treated. In the first experiment 5-pot units of unheated soil were also inoculated in the same way. In these also both the units which received infusions showed less germination and more loss after germination than the unit which received no infusion, though the differences were smaller than in the autoclaved soil. In the second experiment the light inoculation used failed to cause material loss in the unheated soil units, even though two of them were treated with the infusion as in the previous test and two others received triple portions of the infusion.

The experience in the nurseries, in which heavy applications of manure, and especially poorly rotted manure, in a number of cases have apparently resulted in increased disease, and the finding of Fred (43) that green manures recently plowed under favored the work of Corticium have already been mentioned. The addition of dried blood at two nurseries in Kansas was in both cases followed by very much heavier loss than in the controlled plats. The only instances known to the writer in which the addition of organic matter to the soil has shown any indication of materially decreasing damping-off (with the exception, of course, of the organic disinfectants) are the result reported by Gifford (46) with tankage, a single case in the writer's experience with bone meal, and the cases in which cane sugar has seemed to decrease losses somewhat (67). It is of some interest to note that the experience available also indicates increased disease as a result of the addition of inorganic nitrogenous substances. Sodium nitrate and sodium nitrite have both given some indication of increasing damping-off. Ammonium sulphate in six separate series has in every case resulted in decreased stands, though unfortunately in experiments in which the damped-off seedlings were not counted. Ammonium hydroxid, though apparently having some initial value as a disinfectant, as indicated by early damping-off losses, in a number of cases has been followed by very heavy total losses. This experience is of some interest in view of the apparently rather general belief that plants on a soil rich in nitrogen are especially susceptible to disease.

The chemical factor for which there is perhaps the most evidence of a relation to damping-off of conifers is acidity. The fact that sulphuric-acid soil treatment has been found to be one of the most effective means of controlling the disease, that its value is mainly lost if lime is later added to the soil, that soil treatment with sulphur in a number of cases has seemed to decrease the disease, and that lime alone and wood ashes have had either no effect or have apparently increased the damping-off whenever they have been tried, all suggest that soil acidity is not favorable to the disease. Additional indication of this appears in figure 12. The acidity determinations serving as the basis for the graph were made by Dr. L. J. Gillespie, of the Bureau of Plant Industry. The estimates of the relative seriousness of damping-off are very approximate, based in part on observation only. The stations at which damping-off is rated as 1 are places at which it has been reported by nurserymen or foresters as negligible or absent. The estimates for stations 10, 11, 14, and 15 are based entirely on the reports of others, and for station 5 on the basis of counts of damped-off seedlings made by Mr. R. G. Pierce and Mr. Glenn G. Hahn. The writer personally has made the estimates or checked the estimates of the nurserymen at the other stations. A considerable degree of correlation between the hydrogen-ion exponent and the amount of damping-off appears on the face of the graphs, the coefficient being 0.75 ± 0.07. If the correlation is calculated with the H^+ concentration itself instead of its negative exponent, the coefficient, in this case itself negative, is not so high (-0.58 ± 0.11). All of the above data on acidity relation have been picked up incidentally in connection with other work and are merely suggestive. The suggestion, however, seems sufficiently strong to warrant further experimental work directed specifically at the relation between soil acidity and the disease.

The indication in the graph that damping-off is not serious in soils in which the hydrogen-ion exponent (P_H)[6] is less than 6 is of particular interest, in view of the experience of Hawkins and Harvey (71) with cultures of *Pythium debaryanum* on potato juice. They obtained good growth through a range of acidity from P_H 3.4 to 5.8, with no growth or practically none at 3.06 or 8.4. If this represents the acid tolerance of the fungus in the soil solution, it is evident that ordinarily acid soils can not be expected to remain free from damping-off because of inhibition of this particular fungus. This suggests that the apparently salutary influence of soil acidity in decreasing the damping-off of some of the conifers may be exerted in the direction of increasing the resistance of the host rather than of inhibiting the parasites. In any case, it must be kept in mind that as the numerous conifer hosts commonly grown in nurseries have many different habitat preferences and many very different parasites of potential importance, it is not to be expected that there will be found any such constant relation between any factor and the amount of disease as would be expected in a disease in which only a single parasite and a single host are involved.

[6] P_H 6 is equivalent to a hydrogen-ion concentration, expressed in mols per liter, of 1×10^{-6} or 0.000001. The higher the exponent, the smaller the hydrogen-ion concentration. An exponent of 7 means approximate neutrality. In dealing with this exponential form of expression, it should be kept in mind that P_H6 means ten times and P_H5 one hundred times the hydrogen-iron concentration indicated by P_H7. Conversely, the concentration of hydroxyl-ions at P_H7 is one hundred times as great as at P_H5.

BIOLOGIC FACTORS.

Mention has already been made of two strictly biologic factors which may influence the amount of damping-off. Taylor (138) and Rathbun (106) have found Fusarium not only at considerable depths in the soil of pine seed beds, but viable Fusarium spores without hyphæ in the alimentary canals of earthworms and insect larvæ in the soil, and they attribute to the migrations of these and to the tunnels which various animal forms make in the soil a possible importance in the distribution of damping-off Fusaria. A likely relation between *Corticium vagum* epidemics in pine seed beds and the character of the weed flora has also been considered (66).

The relation between the damping-off parasites and other microorganisms in the soil is also a matter of some interest. The effect of the microfauna of the soil on the microflora in general has been considered by Russell and others in a number of papers. The effect of soil disinfection by heat in favoring the work of artificially introduced soil-inhabiting fungous parasites, apparently a rather frequent phenomenon and quite evident in the inoculation experiments with *Pythium debaryanum* reported in the present bulletin, has been in other cases attributed to the removal of bacteria and other fungi which might compete with the parasites (36, 80). Heating soil is known to produce physical changes and also very considerable chemical changes both in organic and inorganic substances. These must not be ignored in considering the effect of previous soil heating on parasite activity. With a view to determining whether all the difference noted in the behavior of *P. debaryanum* in heated soil is due to the direct effects of the heating or in part to the elimination of competing microorganisms, an experiment was conducted in 3-inch pots of autoclaved soil in which 111 of them were inoculated with agar cultures of the Pythium at one point in each pot shortly after seed sowing. The seeds sown in each pot approximated 136, considerably more than are used on equal areas of nursery seed bed. Of these, fifteen 5-pot units and one 3-pot unit had been inoculated broadcast with rice or nutrient agar cultures of various organisms supposed to be saprophytic on pines. These included *Phoma betae*, *Phoma* sp., *Chaetomium* sp. (from a maple root), *Rhizopus nigricans*, *Trichothecium roseum*, *Trichoderma koningi*, *Aspergillus* spp. (including one with black and one with bright-colored spore heads), *Rosellinia* sp. (from soil), *Penicillium* sp., an undetermined bacterium, and three undetermined higher fungi. The whole 78 pots inoculated with *P. debaryanum* and saprophytes, the percentages being based on the total number of seeds in the case of emergence and survival and on the number of seedlings which appeared above ground for damping-off loss, as compared with those which had received the parasite only, gave results as follows:

Pots with saprophytes: Emergence, 47.4±0.86 per cent; damping-off, 9.1 per cent; survival, 41.0±1.23 per cent.

Pots without saprophytes: Emergence, 35.7 per cent; damping-off, 14.3 per cent; survival, 29.2 per cent.

It has been noted in the attempts to diagnose damping-off by planted-plate cultures that when Rhizopus appears *Pythium debaryanum* is not frequently obtained. It is therefore of some interest to note that in this case, in the two 5-pot units which received Rhizopus in addition, the parasite killed only 1.2 per cent and 3.3 per cent, respectively, of the seedlings which appeared above the soil.

At the same time pots not inoculated with parasites were sown, 16 other 5-pot units were inoculated with the same saprophytes as those used in the Pythium inoculated pots, while 25 pots were left entirely without inoculation. A certain amount of damping-off occurred in these pots also as a result of accidental infection. The results were as follows:

Pots with saprophytes: Emergence, 47.8±0.8 per cent; damping-off, 3.9 per cent; survival, 43.7±0.95 per cent.

Pots without saprophytes: Emergence, 43.0 per cent; damping-off, 5.2 per cent; survival, 38.4 per cent.

It is of some interest to note that in these pots also the 5-pot units inoculated with Rhizopus suffered less from damping-off than the average of the saprophyte-inoculated pots.

The probable-error values given above are based on the variability of the emergence and survival figures of the different 5-pot units. No individual figures are available to serve as a basis for the determination of the variability of the pots without saprophytes. The 16 units which support the error determinations are, of course, not a sufficient number to give an entirely reliable index of variability, though these 16 units are respectively derived from the combination of a total of 78 and 80 ultimate units. The distribution of the data appears to be such as to justify the use of probability methods. Of the 64 items which went into the germination and survival calculations, 34 showed a deviation equal to E_s (probable error of a single unit), 9 to a deviation equal to $2E_s$, and only one a deviation equal to $3E_s$.

All of the above figures are based on the results at the end of 10 days after average emergence in the pots. The pots were kept on the benches till practically all damping-off had ceased, 36 days after emergence. As additional accidental infection with saprophytes certainly, and probably with parasites, occurred during this period, the results at the end of the tenth day are considered to give a better indication of the effect of the original inoculations. It is of some interest, however, to note that during the period from the tenth to the thirty-sixth day the difference between the pots to which saprophytes had been added and those which received no saprophytes showed a slight increase, proportionally as well as in the absolute figures. At the end of the 36 days the survivals on all the pots were counted separately. The average number of seedlings per pot were as follows:

Without Pythium:
- Without saprophytes, 42.8±2.3; with saprophytes, 52.1±1.1

With Pythium:
- Without saprophytes, 30.1±2.4; with saprophytes, 48.1±1.4.

The difference in the survivals in favor of the pots with saprophytes in the first case is 9.3±2.5, three and two-thirds times its probable error. In the second case it is 18.0±2.8, more than six times its probable error.

In general, it appears that in this experiment the inoculation of sterilized soil with saprophytes gave the seedlings some protection both against damping-off due to accidental infection with unidentified parasites and from the additional loss caused by light inoculation with *Pythium debaryanum*. The indication is, as would be expected, that only part of the favoring influence of heat sterilization of soil on introduced *P. debaryanum* is immediately due to the elimination of competition with other fungi. If a mixture of different bacteria and fungi had been added to each of the pots instead of but one or two organisms to each 5-pot unit, the effect might have been more marked.

It will be noted that for all the groups (fig. 18), whether with or without Pythium inoculation and with or without added parasites, the frequency polygon is asymmetrical, indicating by its shape, as did the frequency polygon of survivals in pots inoculated with Rheosporangium (fig. 17), that with infections which do not kill all of the seedlings the selection tends to be by pots rather than by seedlings. In other words, in pots in which the parasites succeed in killing any of the seedlings, they usually kill a considerable number. The tendency is illustrated not only by inspection of the graphs, but by the variability of the different groups. The greater variability in survivals between different pots was in both cases in the groups in which both the damping-off after emergence and the survival percentages indicated the largest loss. The percentages of seedlings damped-off during the entire 36 days following emergence and the coefficients of variability of the survivals of the individual pots at the end of that time are as follows:

Without Pythium:
- Without saprophytes, 15.5 per cent damped-off; coefficient of variability, 39±4.2 per cent.
- With saprophytes, 11.1 per cent damped-off; coefficient of variability, 28±1.6 per cent.

With Pythium:

Without saprophytes, 27.5 per cent damped-off; coefficient of variability, 67±7.8 per cent.

With saprophytes, 16.9 per cent damped-off; coefficient of variability, 39±2.4 per cent.

This tendency has been frequently observed in experiments in which inoculum is applied to the soil at the time of sowing. Even in experiments in which a relatively small proportion of the seedlings are killed, some of the pots are nearly or entirely cleaned out. It is taken as an indication that failure of inoculation to give results is often due to the inability of the fungus to maintain itself in a vigorous condition till the germinating seed is far enough along to allow easy infection. It may also be in part due to lack of uniformity of the soil in different pots affecting virulence of parasites or resistance of hosts.

In addition to this experiment on autoclaved soil, a somewhat similar experiment was conducted in a nursery in the Kansas sand hills on soil which had been treated with sulphuric acid, followed by lime raked into the soil. Saprophytes, for the most part the same strains that had been used in the experiment in the greenhouse, were added to 24 plats, each of one-half square foot, of *Pinus banksiana* and 24 of *P. ponderosa*, with 16 interspersed plats of each species serving as controls. The saprophytes were growing on rice, part of which was added to the plat with the inoculum in addition to the fungous mycelium. Damping-off was rather heavy in this soil from accidental infection or from parasites which survived the initial acid treatment, no parasites having been artificially introduced. The loss was probably due to *Corticium vagum* or *Fusarium* spp. rather than to *Pythium debaryanum* in this case. In both pines, emergence was slightly better in the control plats than in those to which the saprophytes had been added, the difference for *Pinus banksiana* being less than half its probable error and for *P. ponderosa* slightly more than its probable error. Damping-off for the first few days after emergence was somewhat less in the controls in one species, but higher in the saprophyte-inoculated pots in the other. The saprophytes therefore gave no evidence of effective competition with the parasites on this acid-lime treated sand.

While the competition for water which seems to be the form of competition most common among green vascular plants is not likely to be of significance between fungi such as those which cause damping-off, a very little observation of the growth of mixed cultures of the parasites and other organisms in Petri dishes is sufficient to make one realize that the latter may very considerably decrease the activity of certain of the parasites. In nutrient agar most of the fungi and bacteria introduced from the soil in attempting parasite isolations, as well as to a less extent the paramecia, nematodes, and amœbæ which develop in such plates, exert a very considerable limiting influence on the growth of most of the damping-off fungi. That they should also limit the growth of parasites in soil, whether by the production of toxic compounds, the exhaustion of food materials, or in other ways, seems entirely reasonable. The results in the writer's experiments on heated soil warrant the suggestion that further trials should be made of the introduction of vigorously growing bacteria or molds, preferably mixed cultures containing a number of different organisms, on seed beds which have been disinfected by some such method as steam or hot water, which leaves the soil in a favorable condition for the development of accidentally reintroduced parasites. If such treatment should be successful in improving the rather disappointing results with soil heating at some nurseries, it might easily become of practical value, as the cultivation of certain of the more easily grown saprophytes on a scale large enough to yield considerable quantities of bacterial or spore suspensions should be fairly easy and entirely practicable in an operation as intensive as that of raising coniferous seedlings.

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SUMMARY.

(1) Damping-off in nurseries is caused mainly by seedling parasites which are not specialized as to host; *Pythium debaryanum* and *Corticium vagum* are probably the most important of these. Damping-off of various herbaceous hosts, including ferns, is often caused by specialized parasites which are limited to a particular host or group of hosts. *Phoma betae* is a rather extreme example of such specialization. For the conifers all the damping-off appears to be due to parasites of the generalized type.

(2) Damping-off of trees, as of herbaceous plants (with the exception of the cases caused by specialized seed-carried parasites), is ordinarily serious only in seed beds or cutting beds in which large numbers of plants are crowded together in a small space. In most of the forest nurseries it is a much more serious matter in conifers than in dicotyledonous seedlings.

(3) The most serious losses in conifers are ordinarily from the root-rot type of damping-off, occurring soon after the seedlings appear above ground and while the hypocotyls are still soft. Losses due to the killing of dormant or sprouting seed by parasites before the seedlings appear above the soil are also frequently serious, sometimes necessarily more so than the later types, as in extreme cases more than half of the seed or young seedlings are destroyed in this way. Damping-off due to infections of parts above the soil surface is serious only under extremely moist atmospheric conditions. The late type of damping-off, in which the roots are rotted after the stem becomes too rigid to be easily decayed, is ordinarily less important than the early types. Seedlings more than 2 months old are ordinarily able to recover from infections by the damping-off fungi. Even after the first month, seedlings with part of their root system killed often recover.

(4) It is possible that damping-off has a certain value as a selective agent by eliminating weak individuals in the seed-bed stage and allowing only the best trees to go into forest plantations. This value, however, is believed to be slight. Disinfectant treatments of seed beds, even when controlling early parasitic losses very well, allow a considerable percentage of disease during the last part of the damping-off period, often as much as occurs at the same stage of development in untreated beds. As it is only this late damping-off in which differences in individual resistance of the seedlings seem to be of importance in determining whether or not they succumb, it is believed that whatever selective value the disease may have will appear in a larger proportion of the damping-off in the treated than in the untreated beds.

(5) Of the different conifers, reports are available as to the susceptibility of 63 species. Species which are especially susceptible at some nurseries may prove more resistant than the average at others. *Pinus resinosa*, which is especially subject to loss at some nurseries, is believed to be so because its growth at these nurseries is slow and its period of susceptibility is therefore especially long. In its early stages it does not seem especially susceptible. Representatives of all the commonly grown genera of the Abietoideæ have been reported by one observer or another as decidedly susceptible. The reports on junipers and other members of the Cupressoideæ, on the other hand, have indicated a considerable amount of group resistance to damping-off.

(6) The best control method appears to be the disinfectant treatment of the seed-bed soil before or immediately after seed is sown. Sulphuric acid has been found very useful for conifers, as they are apparently especially tolerant of acid treatment. No method has yet been worked out to a point at which all of its details are entirely

satisfactory, though the acid treatment has now been in successful use for several years at some nurseries. At most nurseries, if the minimum effective quantity of acid is used, there is no need of any special precautions to prevent injury to the seedlings. It is not expected that any single treatment can be found that can be universally applied without change in details irrespective of differences in soil characters and in fungous flora.

(7) *Corticium vagum* and *Fusarium* spp. have been previously shown to be parasitic on pine seedlings. Different strains of *C. vagum* are found to vary considerably in their ability to cause damping-off, certain strains being consistently destructive and others much less active in tests conducted on different species of pine and several years apart. The differences in activity between strains were greater, and apparently rather more constant from one experiment to the next, than with Peltier's strains in his carnation experiments. Comparison of the results on pine with those of Edson and Shapovalov on potato gives some indication that strains vigorously parasitic on one of these hosts are likely to be parasitic on the other also.

(8) *Pythium debaryanum*, reported on many hosts and proved to be parasitic on few, is shown by repeated inoculation, reisolation, and reinoculation to be capable of causing the damping-off of seedlings of pine species. The identity of the fungus causing the damping-off of conifers with that attacking dicotyledons has been established by cross-inoculations as well as by morphological comparison. Inoculations on unheated soil are much less destructive than on heated soil. *Pythium debaryanum* has been obtained in culture from *Picea engelmanni*, *P. sitchensis*, *Tsuga mertensiana*, *Pinus banksiana*, *P. nigra austriaca*, *P. ponderosa*, *P. resinosa*, and *Pseudotsuga taxifolia*. In addition, fenugreek (*Trigonella foenum-graecum*), cowpea (*Vigna* sp.), and rice (*Oryza sativa*) are reported as apparently new hosts among the dicotyledons. In inoculations the fungus has been successfully used on *Pinus banksiana*, *P. ponderosa*, *P. resinosa*, and in a preliminary experiment on *Pseudotsuga taxifolia*. It had already been successfully used in preliminary inoculations on *Picea canadensis* by Hofmann (77).

Differences in parasitic activity on pine are found between different strains of *Pythium debaryanum*. These differences are not as large and partly for this reason their constancy is not quite as conclusively demonstrated as in the case of the strains of *Corticium vagum*.

(9) *Rheosporangium aphanidermatus* Edson, a parasite of radish and sugar beet, in many ways closely resembling *Pythium debaryanum*, has killed seedlings of *Pinus banksiana* and *P. resinosa* in certain experiments, and reisolations and reinoculations have been

made. The strain available is much less destructive to the pines than most of the *P. debaryanum* strains used, and as the fungus has never been isolated from coniferous seed beds it is not believed to be of any great importance in forest nurseries.

(10) *Phytophthora* sp. from *Pinus resinosa* seedlings has been successfully used in inoculation on *Pinus resinosa* and in a preliminary test on *P. ponderosa.* The strains available have been less destructive to the pines than *Pythium debaryanum* and the stronger strains of *Corticium vagum.* It is not common. Its relation to *Phytophthora fagi*, the European damping-off parasite of both conifers and dicotyledons, which has not been reported in this country, is being investigated.

(11) A fungus referred to *Pythium artotrogus*, also obtained from damped-off *Pinus resinosa*, has indicated a very low degree of parasitism on this host, even less than that shown by the Rheosporangium and Phytophthora strains. An addition is made to the statements in a previous paper concerning the ability of *Botrytis cinerea* to cause damping-off in conifers.

(12) The results of the cultural or direct examination of 742 disease foci in seed beds of various conifers are reported. *Pythium debaryanum* in the plate-culture examination method, considered more reliable than direct examination, appeared in 51 per cent of the foci from untreated beds, while *Corticium vagum* was found in 19 per cent. In foci in beds treated with various disinfectants, *P. debaryanum* was identified in 38 per cent of the foci and *C. vagum* in only 4 per cent. When direct microscopic examination was substituted for isolation, *C. vagum* was found on a larger proportion of the seedlings. It was not found at all in soil which had been heated. The relative ease with which it appears to be controlled by soil disinfection is in agreement with its poor adaptation for aerial distribution. It was found more commonly in cases in which the seedlings were directly examined than when cultures were made. In view of the fact that at least some of the Corticium foci extend rapidly and include very large numbers of seedlings, it seems that the Corticium may be as important as *P. debaryanum* in causing the damping-off of pines.

(13) *Fusarium* spp. have occurred more commonly in plate cultures than either of the above-mentioned fungi. Because little is known as to the parasitism of different species of this group on conifers, it is not possible to make any statement regarding the importance of the individual species. The evidence as a whole indicates so much importance for *Pythium debaryanum*, *Corticium vagum*, and for the *Fusarium* spp. considered as a group that no one of the three can be safely said to be more important than the others. None of the other fungi considered appear to be of real economic rank in the United States.

(14) In an inoculation experiment on the roots of pines $1\frac{1}{2}$ months old, *Corticium vagum* and *Pythium debaryanum* were found able to cause the death of seedlings which had already developed rigid stems and to destroy the younger parts of the roots of seedlings which they were unable to kill. Indications were also obtained of similar but less vigorous action by *Fusarium moniliforme* and *F. ventricosum.*

(15) Data are given confirming the general belief that thick sowing favors the disease and indicating that soil acidity is, in general, unfavorable. Preliminary data on the relation of temperature and moisture to the disease are also presented. The parasitic activity of *Pythium debaryanum* in steamed soil was in one extensive test considerably decreased, following the inoculation of the soil with various saprophytes; this indicates both that competition of different fungi is a factor to be considered and that the inoculation of treated soil with saprophytes may sometimes prove of value in increasing the efficiency of heat disinfection. It is pointed out that with such a complex of parasites capable of producing identical symptoms on a number of different hosts, no relationship between environmental factors and the disease can be expected to hold in all cases.

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Reforestation in Massachusetts

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Under the direction of
F. W. Rane, State Forester

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REFORESTATION IN MASSACHUSETTS.

INTRODUCTION.

The first bulletin issued from this department on the subject of reforestation was published in 1910 by R. S. Langdell, assistant to State Forester Rane. This bulletin becoming quickly exhausted, a second edition with slight additions was offered in 1913. Only a few copies of the second edition now remain.

The present edition is undertaken for the purpose of bringing our experience and practice up to date, after having observed during the last ten years the trees grown in experimental plantations and the effects produced by soil and location in different parts of the State.

While experiments are still in progress we have come to pin our faith more and more to the cone-bearing species, to the elimination of deciduous trees. We must develop a forest that shall be as nearly as possible gypsy-moth proof, as well as immune to destructive disease. To this end we have recommended in the following pages only the trees that, up to the present time, have stood the test.

Inasmuch as the average landowner is more interested in the actual reclaiming of the land than in nursery practice, less space has been devoted in the present bulletin to the forest nursery, and greater emphasis is placed on the handling of young trees in the plantation. To those wishing to establish a forest nursery we recommend government Bulletin No. 76, which may be obtained for a small sum by writing to the Superintendent of Documents, Washington, D. C. The bulletin in hand will give the general principles of this phase of the work, but is intended primarily for those who have purchased nursery stock from the Commonwealth, or from some of the many reliable nursery firms doing business throughout the State.

SYLVICULTURAL CHARACTERISTICS OF TREES RECOMMENDED FOR PLANTING IN MASSACHUSETTS.

White Pine (*Pinus strobus*). — This species is placed first, both because of its marked adaptability to growth in this State and because of the universal demand for its lumber. It is but fair to say that the white pine blister rust offers some menace to clear plantations of this species, especially in Berkshire and Essex counties; but by making mixed plantings, and by eradicating currant and gooseberry bushes in the vicinity, white pine may be relied on to do its part in the conquest of the waste-land problem. Even the two-needle pines suffer from another species of blister rust (the alternate host being sweet-fern), and the owner must expect to lose a few specimens of whatever species he may use through disease, insects, winter-killing or dry weather. The present system of planting provides for more trees than are ultimately necessary on each acre of ground, as well as for thinning, both natural and artificial. A plantation in which white pine represents the *expectation crop*, but in which enough trees of other varieties have been planted to provide for any emergency, is, in our judgment, the practical and ideal undertaking.[1]

The white pine may be found growing in all sorts of situations except in extremely wet soil. This does not mean that the tree grows equally well everywhere, for it undoubtedly prefers well-drained loamy sand, and there reaches its best development. Ideal conditions exist on the slopes and at the bottoms of old glacial deposits, so numerous all over the State.

Reproduction is by seed, which is produced at intervals of from three to seven years, called "seed years."

As regards size and rate of growth, white pine compares favorably with any of our eastern trees, and far exceeds most of them in these respects, reaching the best merchantable size in about fifty years. If left to grow undisturbed it reaches a size excelled only by trees of the Pacific coast, specimens having been

[1] Many of our lumbermen and most of our nurserymen, from their observations and experience, are still of the opinion that they will continue to plant white pine in pure stands as well as in mixed. Likewise, from correspondence and consultation with many of our leading plant pathologists and foresters as to diagnosing the future results of the white pine blister rust, the prevailing impression is that the presence of this disease does not warrant undue fear or exaggeration, or the abandonment of the white pine for reforestation purposes.

Fig. 1.—Four-year white pine transplant.

Fig. 2.—Four-year red pine transplant.

recorded that exceed 200 feet in height, with a diameter of 6 feet, while heights of 100 feet, with 3-foot diameters, are not uncommon.

The chief enemy of the pine forests in this State is fire, which, if it does not kill the trees, so weakens them as to render them liable to attack by several kinds of insects and fungi. The white pine is especially susceptible when young, even a slight ground fire being quite sufficient to completely kill it.

The leading insect enemies are the white pine weevil and the pine aphis. The weevil attacks the main shoot, and in some cases greatly damages young trees up to the age of ten or twelve years. Infested shoots should be pruned and burned during the summer months. The aphis is a small sap-sucking insect, and seldom does permanent damage. A simple spray will easily control it in the event that it appears in large numbers on a small area or on individual trees.

The gypsy moth, while it will eat pines as well as nearly every other kind of tree, does not invade pure stands containing pine alone. The brown-tail moth does not feed on pine.

The many uses of white pine are well known. Among them may be mentioned building timber of all kinds, laths, cabinet material, interior finish, woodenware, matches, flag poles, masts and boxes.

Red or Norway Pine (*Pinus resinosa*). — This tree, while common in northern New England, is not very familiar to residents of Massachusetts. It does not grow in pure stands, but usually in scattered groups with other conifers and hardwoods. The difficulty of collecting the seed in this locality renders the cost of raising the seedlings and transplants very high. Red pine, however, is a very excellent species, and compares favorably with white pine in many respects. It is more nearly immune from the blister rust of two-needle pines than any other member of that group, and represents a safe investment when planted in a favorable location. It prefers a dry sandy loam, outstripping the white pine on gravelly ridges, and will thrive in dry, rocky land. It should never be planted in the swamps or on poorly drained land. In rate of growth the red pine is more rapid than the white when young, though it is shorter-lived in the long run. It reaches a height of 70 to 80 feet, with trunk diameter of 2 to 3 feet, and in old age develops an open, round-topped, picturesque head. The wood is light, hard, close-grained, pale red, with thin yellow sapwood. The lumber is largely used in construction of bridges and buildings, and for piles, masts and spars. For many purposes the lumber is mixed with that of white pine, and the two varieties are not distinguished.

Scotch Pine (*Pinus sylvestris*). — The Scotch pine is the common pine of northern Europe, occupying there the same place that the white pine does in this country as a timber tree. Its growth more resembles our red pine, both in quality of lumber and in the kind of soil preferred by the tree. In common with other pines, Scotch is not much subject to disease and insect attack, but is somewhat more sensitive to fire than red pine. Scotch pine is used for the same purposes as red pine.

Austrian Pine (*Pinus Austriaca,* Endl.) — The Austrian pine has been used successfully in this State in experimental plantations, and is recommended as a substitute for, or in mixture with, Scotch and red pine. It grows on a sandy soil and is a tree of very beautiful appearance, having long and heavy needles. It should not be used for underplanting except where the woods are open, or where heavy thinnings have been made.

Hemlock (*Tsuga americana*). — The hemlock, one of the most tolerant (shade-enduring) of the American conifers, prefers cold north and east slopes of the hillsides. Because of its ability to thrive even in dense shade, it will grow as an understory with other species, evergreen or hardwood, or in pure stands in all stages of growth.

The wood is being more and more used for building timber as the supply of other species grows scarcer, and some dealers prefer it to spruce for rough frame timbers. If care is not used in drying, it is likely to check.

Norway Spruce (*Picea excelsa*). — This is one of the principal timber trees of Europe, and is strongly recommended for planting in this country, possessing, as it does, all of the advantages of our native red spruce, with the added one of being a much more rapid grower. Our experience is that Norway spruce suffers much less from winterkill than pine, and recovers remarkably after suppression by hardwoods. It is especially de-

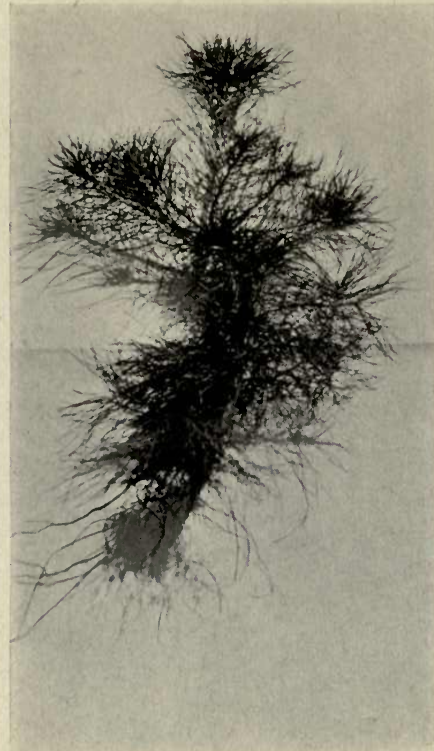

FIG. 3.—Four-year Scotch pine transplant.

FIG. 4.—Evolution of a four-year white pine transplant. Seedling shown in upper left-hand corner is one year old.

sirable for underplanting in hardwood stands, a good combination being spruce and hemlock.

Red Spruce (*Picea rubra*). — This tree is the timber spruce of the northeast, and is now the most important species in New England in size of cut. It will grow in northern Massachusetts on the higher elevations, preferably in mixture with pine and hemlock. It will grow in the shade of other trees for many years, and shows marked recuperative ability when suddenly exposed to the light.

Growth is not rapid, and large size is not reached by this species; but good straight timber is produced, which finds a ready market. The limbs persist, as in the case of white pine, and the best clear timber is grown in mixed stands.

The tree reproduces itself well when the leaf litter on the ground is not too thick, and seedlings start readily under the mature trees of the same species, forming a stand containing trees of all ages.

The uses of the wood are well known, — building timber, piano sounding-boards, inside finish, clapboards and pulp-wood.

American Larch (*Larix laricina*) *and European Larch* (*Larix decidua,* Mill). — The American larch, also known as tamarack and hackmatack, is the only native deciduous conifer in Massachusetts. In winter, after the needles have been shed, it presents the appearance of a dead tree. It bears little resemblance to any of our native conifers, but closely resembles the European larch (*Larix decidua,* Mill), which may be distinguished by its larger cones, stouter twigs and more abundant leaves. The European larch is the more rapid grower, and will thrive in a less moist and less fertile soil than the native species. Larch should be planted in mixture with other trees, among which are recommended spruce, balsam, fir and hemlock. The principal uses are ship and boat timber, telegraph poles, fence posts and railroad ties.

Balsam Fir (*Abies balsamea*). — This tree is of small commercial importance in Massachusetts, but is recommended for certain areas where other more valuable species are hard to propagate, notably in swampy land, and for use in underplanting. It is sometimes planted in mixture and thinned out later for Christmas trees. Tolerance and comparative freedom from insects and disease are arguments in its favor. Experimental plantations made by this department several years ago demonstrate that the balsam fir, like the Norway and red spruce, will hold out under a considerable amount of shade, and resume normal growth when released.

THE FOREST NURSERY.

The forest nursery represents the first step in the work of land reclamation. Seed-plots were at one time a favorite experiment among farmers and landowners, and plantations are in existence that were started in this way. But nature is prodigal in her waste of seed, and it was early discovered that by gathering and planting this waste seed in beds a high percentage could be germinated and brought to an age adaptable to low-cost reforestation. A three-year or four-year transplant may be used in grass or brush land where seed would not have one chance in a thousand.

Procuring the Seed.

The cone-bearing trees differ from the hardwoods in the matter of bearing seed, usually devoting a few years to preparation for a large crop. Our native white pine produces an abundant crop every five to seven years, and bears its seed in cones or burrs, which generally grow in clusters of twos or threes on the upper branches of the tree. There are two seeds at the base of each scale of the cone.

All coniferous seed should be gathered from the trees before the cone-scales have opened. The cones should be spread out on a smooth floor in the sun, raked over from time to time, and finally flayed until the seed has been completely threshed out. This should then be cleaned by winnowing, and kept in bags in a cool dry place, out of the reach of birds and mice. If properly stored the seed in most cases retains its vitality for a number of years.

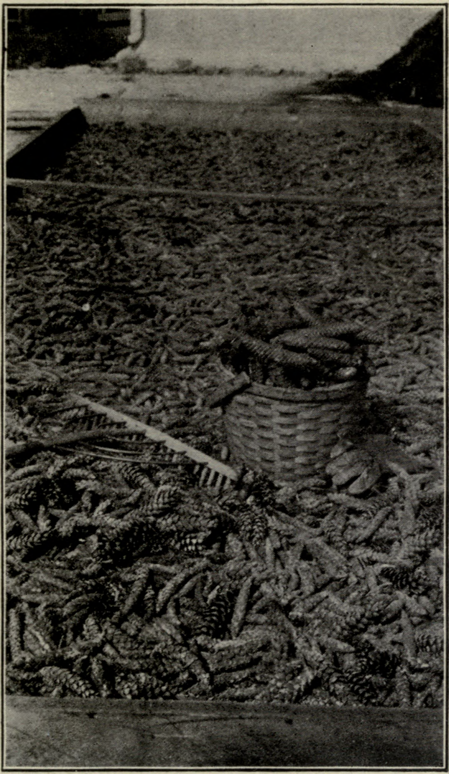

FIG. 5.—Pine cones spread out to dry, in order that seed may be extracted.

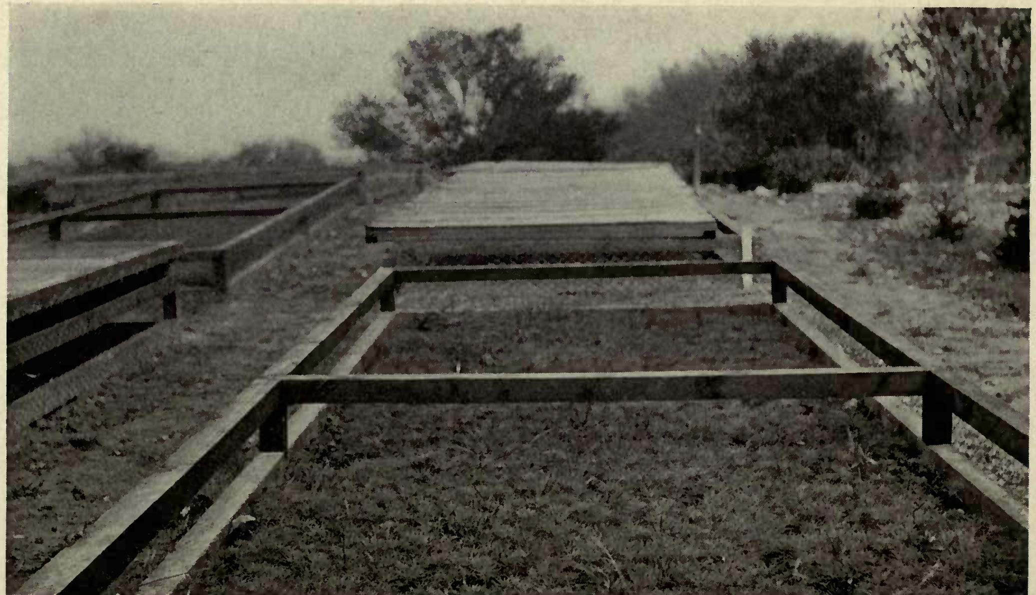

FIG. 6.—A bed 12 by 4 feet, containing about 10,000 one-year white pine seedlings.

Raising Transplants from Seed.

Level or gently sloping well-drained land should be selected for a nursery, the soil being preferably a sandy loam, free from stones. Any length of bed is practicable, but the most convenient width is 4 to 6 feet, with walks 2 feet wide between the beds. The seed is planted in drills or broadcast, according to whether it is desired to leave the seedlings in the bed two years or three years before transplanting. The system that has proved most efficient in our nursery practice in Massachusetts is the construction of 12 by 4 foot beds, with a frame made of lath and fine-mesh chicken wire. The lath gives the young seedlings the proper proportion of light and shade, and the fine-mesh wire protects both seed and seedlings from mice and birds. A burlap cover is used for shading in place of leaves until the seed germinates and appears through the soil, at the end of which time the burlap may be removed for a portion of each day, and finally dispensed with, rolled up and stored for the following season.

A bed 12 by 4 feet takes approximately three-quarters of a pound of seed and produces from 5,000 to 15,000 seedlings, according to the kind of seed used and the success with which they are germinated. Seed may be planted in April or May, but it is usually more convenient to wait until June, when the season for digging transplants is over and more time can be devoted to the work of seeding and care of the new crop.

The seed germinates in about three weeks' time and makes its first year's growth within a couple of months. The seedlings are usually left in the original bed for two years, then transplanted into longer beds and spaced from $1\frac{1}{2}$ to 2 inches apart to prevent crowding. They remain here for two years more, and are then ready for permanent planting on waste land.

A tree so planted is called a four-year transplant, and is the ideal tree for use in reforestation. In old pastures, where the grass is short and there is no great quantity of brush, the two-year seedling may be used with success.

REFORESTATION.

How Trees should be planted.

Heeling in.

When trees have been properly handled at the nursery they will arrive in good condition, packed in damp moss and tied in bundles of 25, 50 or 100, depending on the size and species. Scotch and Austrian pine are more bulky, as a rule, than white pine and spruce. The trees should be heeled in as soon as possible after their arrival. This requires the digging of a trench about 1 foot wide and 1 foot deep, and laid out as nearly as possible east and west. If only a few trees are involved in the shipment, and planting can be accomplished in a few hours' time, no trench will be necessary. It is advisable to first cover the roots with a light layer of earth, pour on a few pails of water, and then cover thoroughly with earth, leaving the tops exposed to light and air. Care should be taken not to cover any portion of the needles with earth, and in the event of dry weather the trees should be watered daily. A covering of burlap or paper will protect them from excessive heat, and will hold back the buds until the trees can be planted. One thousand trees require a trench about 12 feet long.

Requirements for Planting.

We have experimented with various kinds of planting instruments, such as planting irons, bars, spades, etc., and find that the grub-hoe, or mattock, is the most practical instrument for all kinds of soil. Some of our foremen prefer the double-headed mattock, which on one side resembles an axe, and on the other an adz. The axe is used for cutting out a square hole in the sod or leaf-mold approximately 1 foot square, and the adz-like edge for lifting out the earth to a depth of 6 to 8 inches. The average man prefers the single-bladed adz-like mattock, similar to the one shown in Figs. 8 and 9. The most efficient crew consists of two men, one to make the holes and the other to do the planting. The trees are carried in a pail, which should be kept about half full of a mixture of water and

Fig. 7.—Two-man planting crew at work.

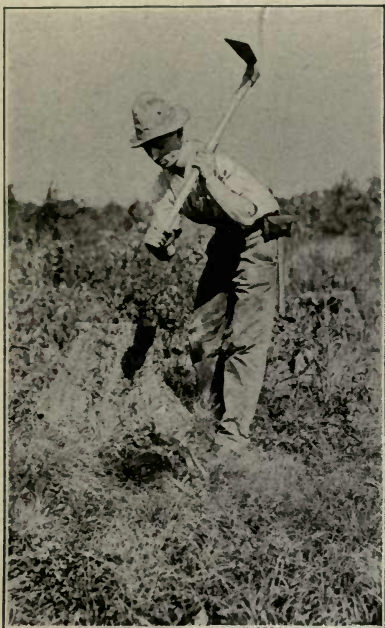

FIG. 8.—First step in making the hole.

FIG. 9.—Second step in making the hole.

FIG. 10.—Setting the seedling and covering the roots.

FIG. 11.—Firming the soil by pressure of the foot.

loam. The bundles should be untied before placing them in the pail. Sod should not be replaced, and each tree should be firmly set by pressing the earth about it with the foot. An experienced two-man crew can plant from 800 to 1,000 trees per day.

Spacing.

The best practice is to space the trees 6 feet apart each way. This method produces a tall, straight bole and prevents undue spreading. Flags may be set up at the end of the field as a guide to the crews, and moved over 6 feet as the end of the course is reached.

On moist situations Norway spruce or balsam fir may be planted alternately with white pine. If the pine is set 6 by 6 feet, and the fir or spruce set in the centers of the squares thus formed, the trees will be evenly spaced 3 feet apart. In from eight to ten years the fir and spruce will yield an incidental revenue if cut and sold as Christmas trees. It has the added advantage of rendering a plantation comparatively safe from any local disease or insect attack that may seriously deplete any one of the species used. And in this connection it may be said that the forest planter would do well to use at least two species of trees, even in the 6-foot spacing. When planting pine the combination recommended is white pine, alternated with red, Scotch or Austrian pine. Spruce may be alternated with hemlock, tamarack or balsam fir.

Number of Trees required per Acre.

Spacing.	Trees.
3 by 3 feet,	4,840
4 by 4 feet,	2,722
5 by 5 feet,	1,742
6 by 6 feet,	1,210
7 by 7 feet,	888
8 by 8 feet,	680
10 by 10 feet,	435

Time to plant.

Planting should be undertaken as soon as the frost is out of the ground in the spring, the months of April and May being preferable, in order that the young roots may get started before the dry season sets in. Spring planting is preferable to fall planting, as the roots having started will not be as likely to be heaved out by the frost; although under certain conditions fall planting is sometimes resorted to, as in a case where a piece of land is too wet to work in the spring, but becomes dry during the summer and fall. The time for fall planting depends largely on the season. The months of September and October are usually best in this State.

Care of the Young Plantation.

An ideal plantation requires very little care until it is old enough to be thinned, which under ordinary conditions would be at about the twentieth year; but preparation against possible disappointment and failure is as necessary in the matter of trees as in the raising of an agricultural crop, and weed-trees choke out a plantation in much the same way that witch-grass chokes out grain.

With the exception of old fields, described on another page, waste land will, in a short space of time, develop hardwood sprouts of questionable value; and even the old fields will occasionally reproduce unexpected crops of gray birch and popple seedlings, to the great detriment of the planted pine.

Most plantations must, therefore, be brushed over, in order that the young pine shall not be shaded out before it has "topped" the less valuable species growing around it. Nature has provided that, in the long run, the conifers will win in the struggle for supremacy, on account of longevity and general good health. But the struggle may last for centuries. The desired result can be obtained in less time through the medium of proper assistance on the part of man. The amount of cost will depend on whether the hardwood brush is simply lopped and left on the ground, or whether it is piled and burned. The latter is the better and safer method, but where the fire hazard is negligible the former is recommended.

FIG. 12.—White pine transplants that were set in the open spaces among scrub oak following a forest fire. The small trees were four years old when set three years ago, and have grown on an average of from 1 to 2 feet each year during the past two years. They will undoubtedly overcome the oak.

Species most easily controlled.

Gray birch and popple, while abundantly prolific, do not cast a dense shade. Where these trees persist, money can be saved by liberal use of the bush scythe on portions of the lot where these trees are abnormally thick. Scattered birch and popple in the young plantation will often do good by supplying a light shade during summer, by rubbing off the lateral branches of the pine, and by helping to develop a long, straight leading shoot. In many cases it is advantageous to go over the plantation with a pair of pruning shears, snipping only the lateral branches of the hardwoods that interfere with the top-most branches of the pine. This method saves expense and develops good pine lumber.

Another species that may be classed under this head is oak, which, while it casts a very dense shade, is slow-growing and may be surpassed in height by the pine, provided the latter is given a reasonable amount of assistance. Where oak alone is involved, one thorough brushing will often meet the requirements, and the pine will gain the ascendency. The better grades of oak may be handled by "limbing up." Scrub oak is an inferior species and should be cut clean. Scrub oak following a fire may sometimes be crowded out in the course of time by planting the pine in the open spaces. This applies especially to certain portions of Cape Cod and Martha's Vineyard. (See Fig. 12.)

Species Difficult of Control.

The trees most difficult of control in the young plantation are the chestnut and the soft maple, on account of their very rapid growth. The chestnut bark disease cannot be depended upon to kill off sufficient sprouts to protect the pine, as sprouts will continue to spring up so long as there is any life in the old stump. Maple is equally fast growing, has no destructive enemies, and casts a dense shade. Repeated brushing is the only protection for a pine plantation made among maple sprouts.

Suggestion for making a Pine Plantation among Dense Hardwood Sprouts.

When pine is greatly desired on land offering strong resistance by reason of its dense hardwood sprout growth, cuttings may be made about 12 to 15 feet apart, and the pines planted in these paths with the usual spacing. It is of course necessary to keep the area on which the pine is planted free from brush. In time a mixed stand will result, composed of protected pine and the best specimens of the prevailing natural hardwoods, in parallel sections. The State Department of Forestry has not undertaken this practice on any large scale, but recommends it on the basis of experiments thus far made.

Another good method which has been tried with success on several of our reforested lots is as follows: with a bush scythe or bill hook cut all hardwood sprouts around each pine over a space about 5 feet in diameter. This allows the pine to keep its main shoot free to the light, and results in a good mixed stand of pine and hardwood.

Fire Lines.

In event of undue fire hazard a good means of protection is to make a fire line around the plantation on the side where the greatest danger lies. This is done by cutting the brush and clearing the ground of all inflammable material on a strip about 50 feet wide. Warning notices may be obtained by application to the State Forester. The fire line is not practicable unless it is kept clean, but when cared for it often proves a vantage point from which destructive fires approaching from a distant area may be turned back and ordinary brush fires may be easily managed.

Types of Land Suitable for Reforestation.

The total area of Massachusetts is about 5,321,787 acres, of which 2,672,950 acres is land adapted only to the growing of trees. Of this area there are about 700,000 acres which at the present time constitute practically worthless tracts, being simply a tax to the owners, who at a very small outlay could bring the land back into profitable forest growth, as well as add to the scenic beauty of the section.

This land lies in tracts varying in size from one to thousands of acres. Practically every farm has a portion which at one time or another has been cut off, burnt over or allowed to lapse into a condition where it is no longer a source of revenue, — a piece of property which brings in no return, though it is still taxable. Lumbermen, mill owners, water-right companies and farmers all have some land which falls under one of the following types, and it is this sort of land which, fortunately, furnishes ideal conditions for forest planting.

Cut-over Land.

Undoubtedly every lumberman in the Commonwealth owns one or more tracts of land which he has cut off, but which has not come back into any profitable growth and which gives no promise of a future crop.

Where the land cut off was previously growing pine it is not always advisable to reforest it the first or second season following, on account of the damage that is almost sure to result from the pine stump beetle (*Hylobius pales*). This beetle breeds in the bark of recently cut pine stumps, but dies out as the bark decays. It chews the bark of young conifers, girdling and sometimes killing them, and damages the lateral branches of larger growth.

Where the land cut off was previously growing hardwoods it is advisable to reforest as soon as possible, as the sprout and hardwood growths, if allowed to gain too great a headway, will hold the transplants in check, and expensive brushing will become necessary. In some cases hardwood sprouts are so persistent as to make reforestation a doubtful investment. Where doubt exists as to the advisability of planting such land, an application should be made to the State Forester for an examination.

Burned Land.

On land which has been subjected to repeated fires, destroying the growth and ground cover, the soil is left free to the action of the weather, to be quickly dried out by the sun, or, if on a side hill, to be washed into the valley by rains. The seed or seedlings which may have been on the ground have been destroyed, and the land might lie for a long period of years before it would reseed itself naturally. Land of this type, therefore, should be set with considerable care, in order to obtain the best results. It is generally advisable to set a four-year-old transplant here rather than seedlings.

Run-out Fields.

Many of the farms throughout the State have been allowed to decline, and are growing up to brush and undesirable hardwoods. Pasture lands especially are being encroached upon by some of our less valuable trees, such as chokecherry and gray birch, which so overshade the ground that good pasturage runs out, and the lot is abandoned for fields affording better forage. In many cases scattering white pines have crept in, and probably in time would seed in the whole piece; but the advanced growth, while doing good work in reseeding, would be of little value, as, growing so scattered, they would develop large lateral branches instead of giving a clear, straight bole so desirable in the best grade of lumber. If the lot could be set out with seedlings, and the trees allowed to grow in sufficiently dense stands, the lower branches would die off naturally, and smooth, clear lumber would be assured.

Underplanting in Thinned Stands.

Where woodland has been extensively thinned to eliminate undesirable species, or for the purpose of marketing the mature timber, underplanting is practicable and advisable. For this purpose a tolerant (shade-enduring) tree is necessary, and among the best species may be named the Norway spruce, the hemlock, the tamarack and the balsam fir. They should be planted in the open spaces as much as possible, or in such a way that they may not grow into the branches of other trees. Otherwise they must be released in a few years' time by cutting the older growth, and damage will result from felling.

Fig. 13.—A thinned stand of hickory. Ready for *underplanting* with spruce or hemlock, or with pine in the more open spaces.

Reforestation Work done by the State.

Under "An Act to provide for the purchase of forest land and for reforestation," passed by the Legislature of 1908, provision is made whereby private landowners may deed tracts of land suitable for reforestation purposes to the State, to be planted and handled under practical forest management, such owners reserving the right to redeem the land at any time within ten years for the actual amount expended. Provision is also made for the distribution of seeds and seedlings at not less than cost to landowners who are citizens of the Commonwealth.

The State has now acquired over 150 tracts of land under this act, comprising in all about 6,000 acres. The number of trees required in planting these areas, and in supplying the State institutions, the Metropolitan Water Board, the cities, the towns and the schools, has been so great that few, if any, have been left over for the private landowner until the present year. During the spring of 1918, however, we distributed at cost more than 500,000 four-year transplants of white and Scotch pine to citizens in all parts of the State. The price charged for these trees was $7 per 1,000, representing the actual cost of raising them in our nurseries.

ACTS OF 1908, CHAPTER 478.

Reforestation Act.

SECTION 1. For the purpose of experiment and illustration in forest management, and for the purposes specified in section five of this act, the sum of five thousand dollars may be expended in the year nineteen hundred and eight, and the sum of ten thousand dollars annually thereafter, by the state forester, with the advice and consent of the governor and council, in purchasing lands situated within the commonwealth and adapted to forest production. The price of such land shall not exceed in any instance five dollars per acre, nor shall more than eighty acres be acquired in any one tract in any one year, except that a greater area may so be acquired if the land purchased directly affects a source or tributary of water supply in any city or town of the commonwealth. All lands acquired under the provisions of this act shall be conveyed to the commonwealth, and no lands shall be paid for, nor shall any moneys be expended in improvements thereon, until all instruments of conveyance and the title to be transferred thereby have been approved by the attorney-general, and until such instruments have been executed and recorded.

SECTION 2. The owners of land purchased under this act, or their heirs and assigns, may repurchase the land from the commonwealth at any time within ten years after the purchase by the commonwealth, upon paying the price originally paid by the commonwealth, together with the amount expended in improvements and maintenance, with interest at the rate of four per cent per annum on the purchase price. The state forester, with the approval of the governor and council, may execute in behalf of the commonwealth such deeds of reconveyance as may be necessary under this section: *provided, however*, that there shall be included in such deeds a restriction requiring that trees cut from such property shall not be less than eight inches in diameter at the butt.

SECTION 3. The state forester may in his discretion, but subject to the approval of the deed and title by the attorney-general as provided in section one, accept on behalf of the commonwealth gifts of land to be held and managed for the purpose hereinbefore expressed. A donor of such land may reserve the right to buy back the land in accordance with the provisions of section two, but in the absence of a provision to that effect in his deed of gift he shall not have such right.

SECTION 4. Land acquired under the provisions of this act shall be under the control and management of the state forester, who may, subject to the approval of the governor and council, cut and sell trees, wood and other produce therefrom.

SECTION 5. All moneys received by or payable to the commonwealth or any one acting on its behalf under the provisions of this act shall be paid into the treasury of the commonwealth.

SECTION 6. Land acquired under the provisions of this act, and subsequently reconveyed under the provisions of sections two or three, shall not be exempt from taxation on account of any plantation of trees set out or planted while it was held by the commonwealth.

SECTION 7. For the purpose of assisting in reforestation a portion, not exceeding twenty per cent of the money authorized by this act to be expended may be used by the state forester for the distribution at not less than cost of seeds and seedlings to land owners who are citizens of the commonwealth, under such conditions and restrictions as the state forester, subject to the approval of the governor and council, may deem advisable.

SECTION 8. The state forester shall replant or otherwise manage all land acquired by the commonwealth and held by it under the provisions of this act, in such manner as will, in his judgment, produce the best forest growth both as to practical forestry results and protection of water supplies.

SECTION 9. All acts and parts of acts inconsistent herewith are hereby repealed.

SECTION 10. This act shall take effect upon its passage.

FORM OF APPLICATION USED IN ASKING FOR AN EXAMINATION OF WOODLAND.

Massachusetts State Forester,

State House,

Boston.

The State Forester is charged with the work of promoting the perpetuation, extension and proper management of the forest lands of the Commonwealth, both public and private (1904, Chap. 409, Sect. 2). The department is open for consultation on forest and shade tree planting, woodlot management, wood and lumber markets, prices, the control of insects and diseases affecting woodland and shade trees, taxation, and all matters pertaining to the care of woodland and ornamental trees. In matters pertaining to fruit growing, however, go to your local county agricultural agent. While good advice can be given through correspondence, office interviews and publications, often a personal examination of the property or trees, themselves, by one of my technical assistants where the advice can be extended on the ground, is the only satisfactory method of procedure. The only charge for such service is the traveling expenses of the forester making such examination. If you care to have such an examination, fill out the attached application blank and mail to our office. A brief description of the land and the problem involved will assist us.

F. W. RANE,
State Forester.

Application for an Examination.

Understanding the condition named above, I desire to have an examination made of a tract of land of approximately .... acres located in the town of.................., State of Massachusetts.

Signed ....

Address ....

Telephone ....

Date.........................191 .