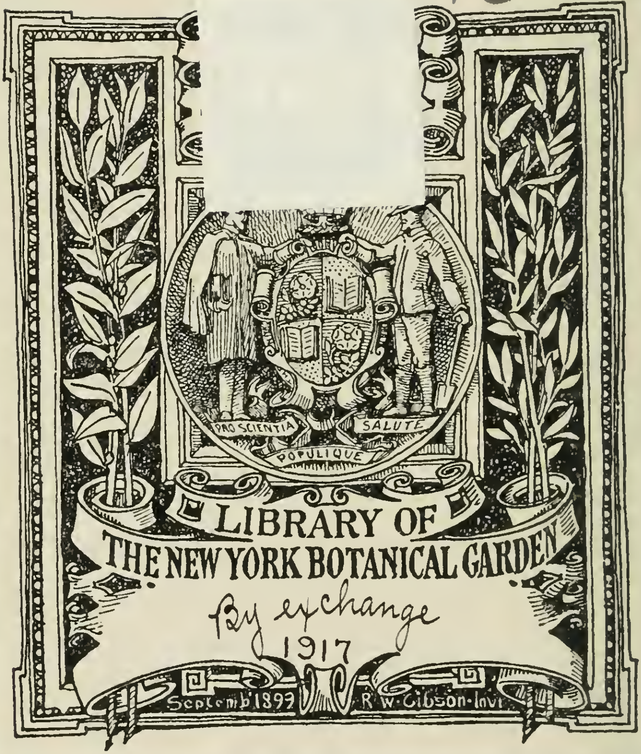
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BULLETIN No. 501

OFFICE OF THE SECRETARY
Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief

Washington, D. C. PROFESSIONAL PAPER February 20, 1917

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By

MORTON O. COOPER, Scientific Assistant
C. M. BENNETT Agriculturist, and
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By Morton O. Cooper, *Scientific Assistant;* C. M. Bennett, *Agriculturist*, and L. M. Church, *Assistant.*

CONTENTS.

THE SCOPE OF THE STUDY.

Concerning an enterprise so extensive as dairying, it is important that something be known of the cost of production of the principal dairy products and the economic factors affecting each. It has been found that by making a detailed study of the business on an individual farm it is possible to draw conclusions which, in a general way, hold true for other farms of the same type operating under similar conditions. By means of carefully kept cost-accounting records the Office of Farm Management has procured data on the cost of producing milk on four dairy farms of the better sort, located in separate and distinctive dairy regions, namely, those of Wisconsin, Michigan, Pennsylvania, and North Carolina. These records cover periods of from four to seven years. It is the purpose of this bulletin to outline the problem of obtaining the complete cost of producing milk on these farms and to show the relationship among the various items making up the total cost, as indicated by the data procured.

LOCATION AND DESCRIPTION OF FARMS FROM WHICH COST RECORDS WERE OBTAINED.[1]

The four farms from which data were obtained for this publication are located, respectively, in Dane County, Wis.; Macomb County, Mich.; Chester County, Pa.; and Edgecombe County, N. C. These farms will hereafter be mentioned as the "Wisconsin farm," the "Michigan farm," the "Pennsylvania farm," and the "North Carolina farm."

THE WISCONSIN FARM.

The Wisconsin farm is representative of milk production on farms where there is an abundance of pasture. This farm, consisting of 550 acres, has about 100 acres of nearly level land under cultivation, and the remainder, which is rolling and sidehill, is in pasture and woods. Most of the rolling land is too rough for cultivation, but has a naturally fertile soil which furnishes an abundant growth of grass throughout the summer months. This farm is best suited to a type of live-stock farming that provides for the profitable use of pasture. Small grain, corn, mixed hay, and alfalfa are grown in the cultivated area. Most of the corn is made into silage. These crops are all fed to live stock, and in addition some concentrates are purchased.

The dairy herd normally consists of about 50 high-grade and pure-bred Jersey cows, two registered bulls, and about 40 calves and young stock. The practice is to have the cows freshen during the early fall, so that the heavy production comes during the fall and winter months, when prices of butter fat are highest. Also, the increased labor required in the production of crops comes at a time when less labor is needed in the care of the dairy herd, thus providing a more uniform distribution of labor throughout the year. For four years, 1909–1912, the milk was hauled to a local creamery and sold on the butter-fat basis. The skim milk was returned to the farm and fed to the calves and pigs. The skim milk not needed for the calves has made it possible to raise 50 to 75 pigs per year. Some young stock is sold, because more is normally raised than is needed to keep up the herd.

THE MICHIGAN FARM.

The Michigan farm is an example of milk production on farms where no natural pasture land is available. This farm, containing about 195 acres, lies well and is practically all tillable land. During the summer 15 to 20 acres are used by the cows for exercise and pasture, and the remainder of the farm is devoted to the production of crops which are consumed on the farm. The whole business of the farm centers around the dairy enterprise, and practically all of the receipts

[1]Acknowledgment is due Mr. C. I. Brigham, of Wisconsin; Mr. Geo. A. True, of Michigan; Mr. C. G. Huey and his father, Mr. A. B. Huey, of Pennsylvania; and Mr. H. L. Brake, of North Carolina, for their hearty cooperation in furnishing the detailed reports that made this publication possible.

are from dairy sales. The herd consists of about 50 grade and pure-bred Jersey cows, one or two bulls, and enough heifers to replace cows discarded and maintain the herd at the desired number. The use of a pure-bred sire and the careful selection of heifers has enabled the owner to increase the value of the herd during the record period. The cows are stall-fed the entire year, and silage has an important place in the ration. The dairy products are sold as milk, cream, and ice cream, and good prices are obtained.

THE PENNSYLVANIA FARM.

The Pennsylvania farm is within the market-milk zone of Philadelphia and is an example of the production of market milk on many diversified farms where dairying is the principal source of income. There is enough rough and rolling pasture land not suitable for cultivation to carry from 40 to 50 head of cattle. The farm contains about 200 acres of fertile and rolling land not unlike many other farms in the southeastern part of the State and the adjacent parts of Maryland. Corn, wheat, and hay are grown in a 6-year rotation. It has been found more profitable to sell wheat and a part of the hay and to buy some concentrates than to grow all the concentrates required for feed. Enough corn is put into silos to make about 200 tons of silage each year; thus the second-year corn land is cleared in time for the sowing of the first-year wheat.

The herd contains about 35 grade cows, some Holstein and others Guernsey; a pure-bred Guernsey bull, and several head of young stock. The milk is shipped in 40-quart cans from a near-by station to a dealer in Philadelphia.

THE NORTH CAROLINA FARM.

The North Carolina farm is in the Coastal Plain region, where dairying is a comparatively new enterprise and the prices received for milk are relatively high. Feed prices, other than for cottonseed products, are also high, for most of the crop land in this region is devoted to cotton and bright-leaf tobacco, and grain and forage are not produced in quantities sufficient to supply local demand. This farm comprises about 120 acres of sandy soil, about half of which is swampy and partially covered with soft pine. The swampy woodland furnishes some pasture. About one-quarter of the crop land is devoted to cotton and tobacco, and the rest to corn, winter oats, cowpeas, and clover, most of which is fed to cows and work stock. Two feed crops can be grown each year. On most of the land more feed can be grown per acre than on any of the three northern farms, because of the longer growing season. The herd is newly established and has increased in value during the record period by the introduction of pure-bred Holstein heifers. It consists of about 20 cows. The milk until 1913 was sold by the gallon to a city dealer. During 1914 the milk was retailed.

METHODS OF PROCURING DATA.

The data contained in this publication were procured by a system of careful cost accounting in which the owner cooperated with the Office of Farm Management. In this system each farmer sent in daily reports showing the hours of work performed by men and horses, the use made of materials, the quantities of feed consumed by the live stock, and the financial transactions, supplemented by explanatory notes. In addition to these reports, individual cow records were kept of milk, feed, and inventory values.

FACTORS INVOLVED IN THE COST OF PRODUCING MILK.

In determining the cost of producing milk it is highly important to know all the factors that must be considered and their relative importance. Indeed, one of the most important results of any cost-accounting investigation is the determination of the different items of expense and their relation to the whole. This relation is of fundamental importance in efficiency studies.

For convenience in studying the results on these four farms, the items of cost are grouped under the headings "Feed and bedding," "Labor," "Use of building," "Use of equipment," "Use of bull," "Interest," "Depreciation," "Miscellaneous items," and "Overhead." These items are summarized in Table I, and the relative importance of each is shown. The ratio between each item and the total cost of keeping a cow per year is quite uniform in different herds where methods of management are similar.

TABLE I.—*Relative importance of factors which make up the cost of producing milk.*

Item.	Actual cost per cow per year.			
	Wisconsin farm.	Michigan farm.	Pennsylvania farm.	North Carolina farm.
Feed and bedding [1]	$49.23	$71.77	$53.77	$68.06
Labor:				
Cows and dairy	29.34	[2] 32.09	21.04	22.63
Marketing milk	2.90	....	3.72	6.41
Use of buildings	6.74	3.98	6.62	6.38
Use of equipment	1.28	2.61	1.45	3.22
Use of bull	1.92	2.87	1.47	3.52
Interest	2.70	3.22	2.07	5.72
Depreciation	....	.99	5.13	3.52
Miscellaneous items	2.67	1.95	2.94	.66
Overhead	4.84	5.97	4.91	7.64
Total	101.62	125.45	103.12	127.76
RELATION OF EACH ITEM TO TOTAL COST EXPRESSED IN PERCENTAGE.				
Feed and bedding	48.5	57.2	52.1	53.2
Labor:				
Cows and dairy	28.9	[2] 25.6	20.4	17.8
Marketing milk	2.8	....	3.6	5.0
Use of buildings	6.6	3.2	6.4	5.0
Use of equipment	1.3	2.1	1.4	2.5
Use of bull	1.9	2.3	1.4	2.8
Interest	2.7	2.6	2.0	4.5
Depreciation	....	.8	5.0	2.8
Miscellaneous items	2.6	1.5	2.9	.5
Overhead	4.7	4.7	4.8	5.9
Total	100.0	100.0	100.0	100.0

[1] On these farms part of the bedding was refuse from the mangers, thus it was necessary to consider feed and bedding as one item.

[2] Includes labor for marketing products.

The variation in numbers of cows in each herd is eliminated by reducing the costs to the cow basis. All cows in each herd, whether milking the full year or not, were considered on the basis of days fed in making the yearly average number of cows. The average number of cows for different years in each herd whose records are considered in compiling the various tables of results per cow are shown in Table II.

TABLE II.—*Size of herds on the four farms, by years.*

Year.	Wisconsin farm.	Michigan farm.	Pennsylvania farm.	North Carolina farm.
1909	49.50	58.00	....	16.38
1910	43.00	52.81	36.58	14.17
1911	44.43	49.80	31.75	12.67
1912	45.45	46.30	38.44	15.50
1913	....	....	36.70	18.75
1914	....	....	....	20.60
Average	45.60	51.73	35.87	16.35

FEED AND BEDDING.

On all the farms the most important of the cost items in the production of milk is the expense for feed. In fact, this item is of such proportions that it is often used alone in connection with value of products in studying the relative profitableness of individual cows in the same herd. Frequently the mistake is made, in the absence of the full consideration of all the factors of cost, of figuring as net profit the difference between milk receipts and feed cost. On the Wisconsin, North Carolina, and Pennsylvania farms the feed is approximately one-half of the total cost. On the Michigan farm this item is 57.2 per cent of total cost. The difference is caused by a difference in method of feeding. The first three herds depend largely upon pasture for summer feed, while the fourth is stall-fed throughout the year.

In connection with this point it may be of interest to examine the feeding practice on each of the four farms. A word regarding feed costs is important for the purpose of showing how they were determined. Farm-grown feeds were charged to the cows at farm value, which varied somewhat with the locality and quality. All purchased feeds were charged at actual cost, the hauling being included in the charge for labor.[1] Pasture was valued at the customary rate in each locality. Any charges for bedding are included with feeds under the heading of dry roughage. For the most part, however, the bedding consisted of refuse from the mangers, supplemented with straw and spoiled fodder, which had little or no value above the labor of hauling. The actual quantity for which a charge is made is so small on these farms that it is questionable whether bedding need be considered in the heading with feed.

[1] It should be observed that these costs were obtained prior to 1915, and in making application of these figures due allowance should be made for variations in the cost of feed, etc.

THE WISCONSIN FARM.

Table III gives a summary of the quantity and cost of feed consumed per cow by the Wisconsin herd for the years 1909 to 1912. The actual cost of feed and bedding varied but little from year to year. However, there was a gradual and distinct change in the feeding methods. The concentrates were usually fed in the form of a mixture. The principal feeds in the mixture were in the proportions of six parts corn, three parts bran, one part each of oil meal, cottonseed meal, and gluten feed. In 1909 each cow averaged nearly 1 ton of concentrates. This was decreased during each succeeding

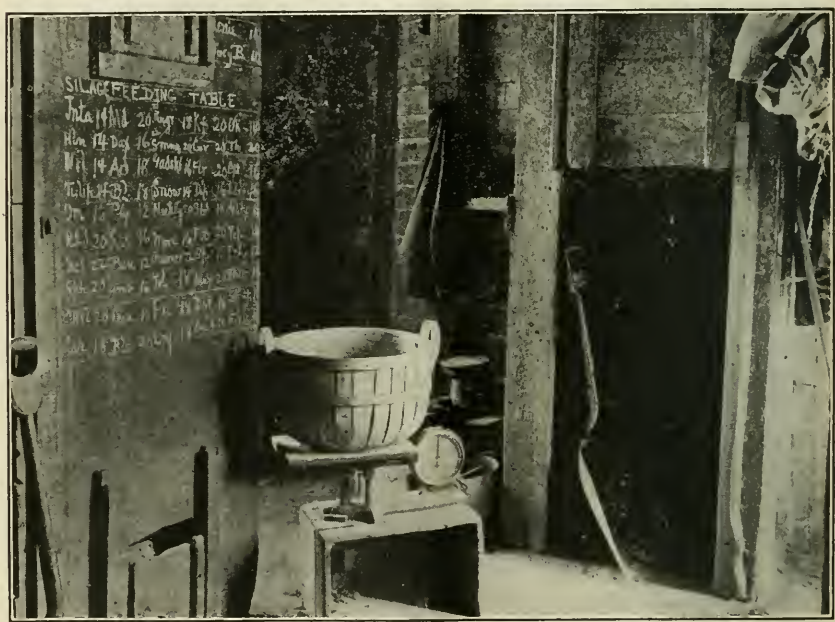

FIG. 1.—Outfit for weighing silage on Wisconsin farm. Silage, as well as the grain ration, is weighed out to each cow. The owner finds that a definite feeding system results in increased production.

year, and in 1912 the average quantity per cow was 1,300 pounds, or a little over 7 pounds per day for the period fed in the barn.

The dry roughage consisted of clover, alfalfa, mixed hay, corn stover, and straw for bedding. The quantity varied with the proportion of each kind of roughage used and its quality. The decrease in the quantity of concentrates and dry roughage per cow was partially offset by a gradual increase in the quantity of silage. (See Fig. 1.) The pasture period varied with the season. The increase in cost the last year is due to an increase in pasture value. In spite of variations in quantities the total feed cost was nearly constant throughout the four years.

The average price per ton of the mixture of concentrates for each of the years was $26.56, $24.26, $24.40, and $29.40, respectively, the average for the four years being $26.16. The average price per ton of all dry roughage ranged from $7.51 to $11.48, the average for the four years being $8.71. The four-year average price of alfalfa was $12.75, mixed and clover hay $8.50, and corn stover $3.04 per ton. Silage, including some green corn, was valued at from $3.13 to $4 per ton, the yearly average being $3.68.

TABLE III.—*Annual quantity of feed and its cost per cow on the Wisconsin farm.*

Year.	Concentrates.		Dry roughage.		Silage.		Pasture.		Total feed cost.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Days.	Value.	
	Pounds.		*Pounds.*		*Pounds.*				
1909	1,920	$25.52	2,005	$8.53	6,754	$10.59	184	$6.02	$50.66
1910	1,600	19.42	2,546	9.55	7,010	14.02	214	6.42	49.41
1911	1,588	19.78	1,780	7.70	7,160	14.32	184	6.10	47.90
1912	1,310	19.26	1,297	7.46	7,401	13.20	198	8.83	48.75
Average, 4 years	1,605	21.00	1,907	8.31	7,081	13.03	195	6.84	49.18

THE MICHIGAN FARM.

Table IV gives a summary of the quantity of feed consumed per cow and its costs for the Michigan farm herd for the years 1909 to 1912. Only the last three years are considered in obtaining an average to show the typical feeding methods practiced on this farm. The smaller quantities and value of feeds consumed per cow in 1909 are due to the fact that a number of heifers were fed in the herd the full year, although not giving milk except for a few weeks toward the end of the year. The larger quantity of concentrates and silage per cow on this farm for the year does not mean a larger daily ration, since the cows were stall-fed throughout the year. The use of the lot for pasture and exercise was charged to them on the basis of cost for interest, taxes, and fencing repairs. Expenses for feed and bedding are quite uniform for 1910 to 1912. Approximately 47 per cent of this feed cost is for concentrates, 26 per cent for dry roughage, 25 per cent for silage, and 2 per cent for pasture. The concentrates were fed in the form of mixtures, consisting principally of bran, dried beet pulp, cottonseed meal, gluten feed, and ground beans. Bran was usually purchased in carload lots. The average price per ton of the mixture of concentrates was $21.84, $22.92, $24.78, and $23.52, respectively, the four-year average being $23.36. About one-third of the dry roughage consisted of alfalfa, and most of the remainder was timothy and clover hay, the average price per ton of each being $17.74 and $12.61, respectively. A small quantity of corn husks and straw valued at $5 per ton was used. The average yearly price for all dry roughage was $14 per ton, and silage was valued at $3 per ton each year.

TABLE IV.—*Annual quantity of feed and its cost per cow on the Michigan farm.*

Year.	Concentrates.		Dry roughage.		Silage.		Pasture.[1]		Total feed cost.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Days.	Value.	
	Pounds.		*Pounds.*		*Pounds.*				
1909	2,220	$24.24	2,900	$10.85	9,880	$14.81	....	$1.94	$51.84
1910	2,940	33.70	3,040	19.78	12,240	18.36	....	1.24	73.08
1911	2,854	35.38	2,606	17.08	11,572	17.38	....	.95	70.79
1912	2,770	32.60	2,342	19.10	11,103	16.72	....	2.88	71.30
Average, 3 years[2].	2,855	33.89	2,663	18.65	11,638	17.49	....	1.69	[2] 71.72

[1] Charge for use of lot used throughout the year for exercise.
[2] The year 1909 not included in average.

THE PENNSYLVANIA FARM.

Table V gives a summary of the quantity and cost of feeds consumed per cow by the Pennsylvania farm herd, 1910–1913.

TABLE V.—*Annual quantity of feed and its cost per cow on the Pennsylvania farm.*

Year.	Concentrates.		Dry roughage.		Silage.		Pasture.		Total feed cost.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Days.	Value.	
	Pounds.		*Pounds.*		*Pounds.*				
1910	1,399	$17.06	2,020	$10.23	7,537	$14.42	154	$3.55	$45.26
1911	1,486	19.76	1,908	7.52	8,915	21.28	178	4.10	52.66
1912	1,332	16.71	2,455	12.77	8,032	19.47	193	4.44	53.39
1913	1,473	17.51	2,847	9.39	8,760	21.89	221	5.08	53.87
Average, 4 years.	1,423	17.76	2,308	9.98	8,311	19.27	187	4.30	51.30

In feeding concentrates, not as much difference was made in the quantity given to low yielding and high yielding cows as would have been made had the production per cow been used as the basis of compounding the ration. The difference, however, amounted to as much as $13 per year in the value of concentrates fed to individual cows. The mixture of concentrates, for the most part, consisted of sucrene and corn-and-cob meal. Some brewers' grains, gluten feeds, cottonseed meal, and dried beet pulp, were used. The dry roughage consisted of corn stover, alfalfa, and mixed hay, and wheat straw for bedding. The variation in total quantity from year to year is due largely to the difference in the quantity of corn stover. Although the quantity of silage varies somewhat from year to year, the average is about four tons per cow per year. The pasture season was increased each year by making greater use of the aftermath on hay meadows. The average price per ton of concentrates for the four years was $24.38, $26.60, $25.10, and $23.78, respectively, the average per year being $24.95. The average price per ton of all dry roughage varied from $6.60 to $10.40, the average per year being $8.65. The charge made for silage varied from $3.83 to $5 per ton, the average per year being $4.64.

NORTH CAROLINA FARM.

Table VI gives a summary of the quantities and cost of feed consumed per cow by the North Carolina farm herd, 1908–1914, inclusive. Owing to a marked change in the method of feeding in 1914, when the cows were stall-fed most of the year, the figures for this year were omitted in making a representative yearly average for the farm. The kinds of feed available on this farm, owing to its location, are distinctly different from those on the three northern farms. The basis of the concentrates used in the ration was cottonseed meal supplemented with dried beet pulp. Small quantities of gluten feed, bran, corn meal, and patent feeds were also used. The concentrates were mixed and apportioned to the cows on the basis of individual production, and the quantity fed per cow increased from year to year. A large portion of the dry roughage was cottonseed hulls, which were purchased locally at about $6 per ton. Other roughage consisted of home-grown hay, made from peanut vines, soy beans, cowpeas, and mixed grasses and clover. Beginning in 1909, the addition of silage to the ration resulted in a reduction of both concentrates and dry roughage. However, each succeeding year a larger quantity of concentrates was fed, while the dry roughage remained about constant, except for 1914, when the cows depended less on pasture.

TABLE VI.—*Annual quantity of feed and its cost per cow on the North Carolina farm.*

Year.	Concentrates.		Dry roughage.		Silage.		Soiling crops.	Pasture value.	Total feed cost.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.			
	Pounds.		*Pounds.*		*Pounds.*		*Value.*		
1908	1,957	$28.06	6,261	$21.07	....	....	....	$4.05	$53.18
1909	1,627	23.36	4,566	13.69	5,268	$13.18	....	3.88	54.11
1910	2,137	32.37	3,793	14.33	2,712	6.78	$3.67	4.41	61.56
1911	2,616	40.40	3,771	12.91	6,800	17.00	....	3.02	73.33
1912	2,740	36.12	3,781	9.78	3,013	7.53	3.27	3.50	60.20
1913	2,843	41.60	3,613	12.08	5,407	13.53	....	3.76	70.97
1914	3,107	45.04	5,298	16.57	6,223	15.56	6.95	1.36	85.48
Average, 6 years[1]	2,320	33.65	4,298	13.98	3,867	9.67	1.16	3.77	62.62

[1] 1914 not included in average.

During three summers soiling crops were used to supplement silage. The increased total quantity of feed consumed each succeeding year is reflected in an upward trend in the total cost of feed per cow for the period. Variation in the price per ton of corn-and-cob meal is reflected in the total cost of feed. From 1908 to 1914 the prices per ton paid for this meal, bought in large quantities, were, by years, $28.55, $28.54, $30.07, $31.04, $25, $26.50, $27, and $22, the average per year for the period being $28.13. The price of beet pulp ranged from $29.30 to $32, with an average of $30.57. The price per ton of the feeding mixture varied from $26.36 to $30.89, the average being $29.03. The price per ton of corn stover ranged from $5 to $6. Hay ranged from $4 to $10 per ton, according to kind and quality. Silage was valued at about $5 per ton. The average price of all dry roughages ranged from $5.17 to $8.13, with an average of $6.51. Owing to the prices of feed materials in this section the average cost of feeding a cow on this farm is high.

These records show that a ration having as a basis cottonseed meal, even at southern prices, is more expensive than a ration with corn as a basis at prices prevailing on northern farms at the time of this investigation. The concentrates on this farm constitute 54 per cent of the total feed cost, which is from 7 to 20 per cent higher, proportionately, than on the three northern farms.

LABOR.

In the production of milk the cost of labor on these four farms is second in importance to feed. As shown in Table I, the labor is approximately one-fourth of the total cost of keeping a dairy cow, or about one-half the cost of feed. This labor includes the work of men and horses required to feed and care for cows, handle the milk, and market the products. Man labor is charged on the basis of the complete cost of hired labor on each farm; that is, the rate per hour is obtained by adding to the cash wages the value of board and other perquisites and dividing this total by the total number of hours of all hired labor. Horse labor is charged on the basis of cost, and the rate per hour is obtained by dividing the total cost of keeping the horses on the farm by the number of hours of horse work.

TABLE VII.—*Number of hours of man and horse labor required per cow per year to produce milk and deliver it at the railroad station on each of the four farms.*

Year.	Wisconsin farm.		Michigan farm.		Pennsylvania farm.		North Carolina farm.	
	Man labor.	Horse labor.	Man labor.	Horse labor.	Man labor.	Horse labor.	Man labor.	Horse labor.
	Hours.	*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*
1909	213	41	195	28				
1910	214	38	260	32				
1911	205	28	236	35			268	74
1912	224	24			189	20	277	46
1913					151	22	242	46
1914							[1] 507	[1] 130
Average	211	33	230	32	170	21	262	55

[1] 1914 not included in average.

Table VII gives the hours of labor required per cow for each of the four farms. The highest labor requirement is on the North Carolina farm. This is due, in part, to the fact that the herd is the smallest and the distance to market greatest. The extra labor of bottling and retailing the milk in 1914 accounts for the greater labor requirement of the last year. Owing to this extra labor for retail marketing figures for this year are omitted in the farm average.

The lowest labor requirement per cow is on the Pennsylvania farm, where the milk is handled quite efficiently and delivered at a near-by railroad station. The fact that the cows receive less individual attention and on the average produce less may have some influence in making the labor requirement lower. The use of a milking machine during 1913 made the man-labor requirement 38 hours per cow less than for 1912. The actual time of milking was reduced about one-half. The horse labor, mostly used in delivering milk, remained about the same each year. With the exception of the Pennsylvania farm, the average man-labor requirement per cow, exclusive of marketing, on each of the farms for all years is approximately 200 hours. This is equivalent to an average of 33 minutes per cow per day, 365 days in the year.

The hauling of milk to market is a daily operation on each of the farms. The hours of labor required per cow for this work varies with distance from market, size of the herd, and condition of the road. On the Pennsylvania farm it required 13.4 hours of man labor for this work as compared to 40.3 hours on the North Carolina farm, where less milk was hauled about four times as far. On the Wisconsin farm, 1 mile from the creamery, it averaged 16 hours per cow.

It is of interest to compare the man-labor requirement on the North Carolina farm in 1914 with other years. For nine months of this year the milk was retailed in the same city where it had previously been sold in bulk to a dealer. The actual hours of man labor required at the farm increased from an average of 222 hours per cow to 358 hours. This increase of 136 hours represents mainly the increased labor for extra handling and bottling the milk and caring for equipment put in use when the change was made to selling at retail. The time spent in marketing increased from 40 hours to 149 hours per cow. The horse-labor requirements increased in like proportion.

Table VIII gives the wage rates per hour for man and horse labor that were used in charging each herd for labor. The average rate per hour of man labor varied from 9 cents on the North Carolina farm, where the wages paid hired labor were low (about $20 per month with board and lodging), to nearly 14 cents on the Wisconsin farm, where more efficient men were paid wages that averaged about $32, with board and lodging.

TABLE VIII.—*Cost per hour of man and of horse labor on the four farms.*

Year.	Wisconsin farm—rate per hour.		Michigan farm—rate per hour.		Pennsylvania farm—rate per hour.		North Carolina farm—rate per hour.	
	Man.	horse.	Man.	Horse.	Man.	Horse.	Man.	Horse.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1909	13.3	10.0	12	8				
1910	14.2	8.9	12	8				
1911	13.6	7.9	12	8			9.1	7.7
1912	13.6	7.9	12	8	12.9	11.8	9.0	8.0
1913					13.9	8.8	10.4	8.0

USE OF BUILDINGS.

The charge for the use of buildings is made up of interest, taxes, depreciation, and repairs on the buildings used for sheltering the cows and the necessary storage of cow feed. Interest was figured at the rate of 5 per cent on the average of the inventory value taken at the beginning and end of each year's record. The actual expense for repairs were taken from the financial and labor cost records. The farm taxes were apportioned to each enterprise on the farm on the basis of actual inventories of taxable properties. The charge for use of buildings was prorated to individual cows on the basis of the average number in the herd. It is expected that the charge per cow

FIG. 2.—Barn on a dairy farm in southeastern Pennsylvania, in which the annual charge per cow for shelter is less than $5 per year. The pasture, conveniently located, helps to keep down the labor charge.

for the use of buildings will vary on different farms, depending upon the housing efficiency, the value of the buildings used, and the size of the herd. It is not uncommon to find farms on which the dairy buildings are too high-priced to allow even a reasonably good cow to show a profit after paying her share of the annual cost for such buildings. The buildings on these four farms furnish adequate shelter for the cows at a moderate cost per cow. (See fig. 2.) The average yearly charge varies from 3.2 to 6.6 per cent of the total cost of keeping a cow. The average of the four farms is $4.74 per cow.

USE OF EQUIPMENT.

The charge for the use of dairy equipment is relatively small. Although the rate of depreciation on dairy utensils is high, the amount of capital so invested per cow at any one time is comparatively small. Dairy equipment includes such items as separators, coolers, wagons, pails, cans, bottles, and other miscellaneous articles used in connection with the care of milk and the cows. The annual cost for these items includes depreciation, repairs, and interest on the average capital invested. The depreciation is the difference between the inventory value at the beginning of the year, plus the sum of all items purchased, and the inventory value at the end of the year. On these four farms this equipment charge, as shown in Table 1, ranges from $1.28 to $3.22 per cow, which is from 1.3 to 2.5 per cent of the total cost of the cow per year.

USE OF BULL.

The net cost of keeping a bull is one of the expenses of producing milk. This cost includes feed, labor, interest, and depreciation. The last two items are in proportion to the value of the bull. Where heifers are raised to maintain the herd it has been proved to be poor economy to keep a scrub bull, however low the cost. The increased value at birth of the heifers sired by a bull of high quality will far more than offset the increased charge for use of the better bull. The size of the herd is also an important factor affecting the cost per cow. The charge for use of bull varies on each of the four farms, according to the number of cows and the value of the bull. This ranges from $1.47 to $3.52 per cow, the average being $2.44. This is from 1.3 to 2.7 per cent of the total cost of keeping a cow. The highest charge is in the smallest herd, and the smallest charge is in the herd where there is the largest number of cows per bull.

INTEREST.

There is a certain amount of money invested in the cows of the dairy herd upon which the owner is entitled to receive interest. In these records interest is charged at the rate of 5 per cent on the average value of the cows for the year. This item ranges from 2 to 4.4 per cent of the total cost. The high interest charge on the North Carolina farm is due to the fact that several pure-bred Holstein heifers were purchased during the record period.

DEPRECIATION.

Some of the factors influencing depreciation charge are udder troubles, failure to breed, abortion, minor accidents, age, and death. Usually the loss from death is small compared with the shrinkage in value of cows sold at meat prices. The formula used in determining depreciation on each of the four herds is: First inventory value plus the value of cows entering by purchase or otherwise, minus the second inventory value plus the receipts from sales of cows, equals the amount of depreciation for any given period. The depreciation per cow for each year was determined by dividing the total for the herd by the average number of cows.

On the Wisconsin farm there was no charge for depreciation, and only a small charge on the Michigan farm. The average value per cow increased from year to year in both of these herds during the record period. Grade cows were sold while still valuable for dairy purposes, and their places were filled by pure-bred heifers of home raising. The highest depreciation charge, $5.13 per cow, is on the Pennsylvania farm, and, considering the average valuation per cow, this is a small charge. It is probable that, owing to the herd management, the charge for depreciation is lower on each of these farms than may be expected for a period of years on most dairy farms.

MISCELLANEOUS ITEMS.

There are a number of minor expenses in connection with the maintenance of every dairy herd, and for convenience these may be grouped under the heading of "miscellaneous items." These include veterinary services, fees to cow-testing association, registration fees, ice, and other dairy supplies. The total of these varies on each of the four farms, ranging from 66 cents to $2.93 per cow, which is from one-half of 1 per cent to nearly 3 per cent of the total cost.

OVERHEAD.

There are a number of items of expense in the operation of a farm business that can not be charged directly to the individual enterprises. Important in this group are expenses for the general upkeep of the appearance of the farm, interest on money borrowed for general working capital, farm share of telephone rental, postage, and stationery. The importance of this item may be expected to vary greatly with the efficiency of management of the farm business. On these farms the overhead expenses were distributed to the productive enterprises on the basis of total cost for labor and materials. The dairy being the most important enterprise, it is made to carry its proportionate share. Overhead on these four farms varies from $4.84 to $7.64 per cow, and is 5 to 6 per cent of the total cost.

CREDITS OTHER THAN MILK.

There are certain credits apart from milk and milk products, such as value of manure, calf, and in some cases an appreciation in value of cows, which must be considered in determining the net cost of milk. While these credits affect the net cost of milk, they in no way change the proportion of any of the factors entering into the gross cost per cow; because, were the credits subtracted from each factor rather than from the total, the amount subtracted would be prorated to each item on the percentage basis. The total credits other than for dairy products on these farms range from $12.27 to $20.33 per cow and will offset from 25 to 30 per cent of all costs other than feed. (See fig. 3.)

TABLE IX.—*Items of credit other than milk, their annual value per cow, and their relation to cost other than feed on the four farms.*

Item.	Wisconsin farm.	Michigan farm.	Pennsylvania farm.	North Carolina farm.
Manure	$10.47	$15.42	$10.27	$10.64
Calves	4.75	4.52	1.16	4.16
Hides	.11	.08		.26
Bull service	.05			.53
Feed sacks		.30		
Premiums			.84	1.22
Total	15.38	20.32	12.27	16.81
Per cent of costs other than feed	20.3	28.7	24.8	27.2

Table IX gives these credits for the four farms, their amount per cow, and the relation which they bear to the costs other than feed. (See Table I.)

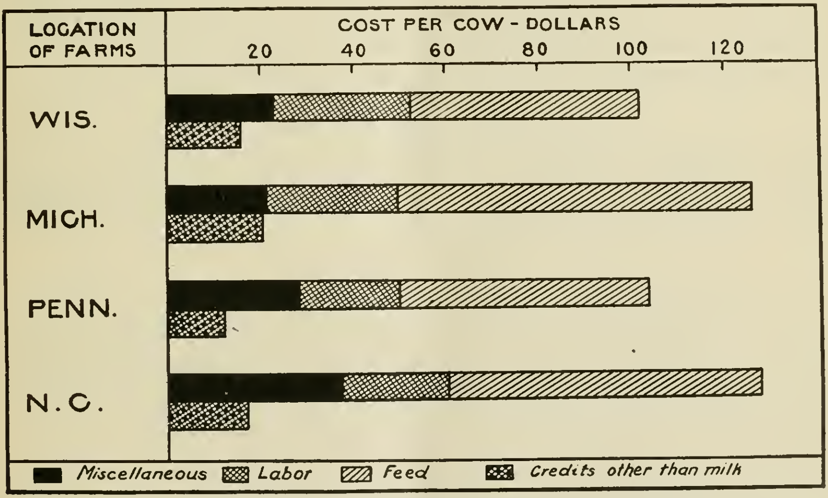

FIG. 3.—Relation between the credits other than milk and the total cost of keeping a cow on each of the four farms.

VALUE OF MANURE.

Manure is the most important credit. This was valued at $15 per head per year for the Michigan farm and $10 per head on each of the others. The value of manure produced by the herd bulls was credited to the cows, which accounts for the increase in the figures given in Table IX. The higher rate per cow on the Michigan farm is attributable to the fact that the cows are fed in the barn all the year, and thus more manure is recovered than on the other farms.

These values are figured on the basis of a ton of manure being worth \$1 at the barn and on a production of approximately 1¼ tons per cow per month during the period they are kept in the stable. From the data on three of these farms, showing the quantity of manure actually hauled to the fields, it is evident that the credit given for manure is liberal. It is easy to overestimate the actual credit value of manure per cow, and before deciding on a definite valuation for any herd it may be well to consider the care taken of the manure and the quantity that is actually returned to the land where crops can use it.

VALUE OF CALF.

The value of calves at birth depends upon their breeding and sex. Heifer calves from high-producing grade cows are usually valued higher than males. In regions where the main product of the dairy is market milk the common practice is to raise but few of the heifer calves. All the bull calves and most of the heifer calves are disposed of shortly after birth. On the Pennsylvania farm the number of heifers selected for raising was relatively small as compared with the numbers sold or killed at birth, so that the credits for calf values in this herd is low, amounting to but \$1.16 per cow. Calf credits on the other three farms are \$4.16, \$4.52, and \$4.74 per cow.

MINOR CREDITS.

Certain minor credits are shown on these farms as receipts for sale of hides, fees for bull services, fair premiums, and rebates for feed sacks.

APPRECIATION CREDIT.

In some herds for certain years, or for a period of years, there may be a credit for appreciation. This may be the result of careful management in building up a higher producing herd by using a pure-bred sire and the introduction of pure-bred cows. This method of management accounts for the appreciation of \$6.37 per cow on the Wisconsin farm. Adding this appreciation credit to the \$15.38, as given in Table IX, the percentage of costs other than feed offset by credits on this farm is increased from 29.3 to 41.2 per cent. On the North Carolina farm there is an appreciation for one year, which is more than offset by the depreciation of other years, and the result is an average net depreciation of \$3.52 per cow, as shown in Table I.

The question of depreciation is discussed farther on (see p. 26.)

QUANTITY OF MILK PRODUCED.

Table X gives the average quantity of milk produced per cow on the four farms for each year production records are available. On three of these farms the yearly average is little over 5,000 pounds per cow, while the Michigan farm shows a production above 6,000 pounds. In 1909 several heifers were added to the Michigan herd, and their yield, while not low for heifers, pulled down the average. Heifers also account in part for the lower yields on the Wisconsin farm for 1910, 1911, and 1912. Frequent individual butter-fat tests were made on all except the North Carolina farm. Of these, the two Jersey herds, Wisconsin and Michigan, have an average production of 256 and 281 pounds of butter fat, respectively, which gives an average test of 4.89 and 4.47 per cent, respectively.

According to the Thirteenth United States Census (1910) the average milk production per cow in the 10 leading dairy States is less than 4,200 pounds, and the State showing the highest production has an average of but 4,470 pounds. From this comparison it may be seen that the herds on each of these four farms are representative of good dairy herds.

TABLE X.—*Quantity of milk and butter fat produced per cow per year on each of the four farms.*

Year.	Wisconsin farm.			Michigan farm.			Pennsylvania farm.			North Carolina farm.
	Milk.	Butterfat.		Milk.	Butterfat.		Milk.	Butterfat.		Milk.
	Pounds.	*Per ct.*	*Pounds.*	*Pounds.*	*Per ct.*	*Pounds.*	*Pounds.*	*Per ct.*	*Pounds.*	*Pounds.*
1909	5,550	4.93	274	5,590	4.44	247	....	....	....	3,988
1910	5,245	4.90	257	6,721	4.48	301	5,805	4.0	232	4,542
1911	4,990	4.91	245	6,722	4.45	299	5,483	4.2	230	4,983
1912	5,130	4.82	247	6,102	4.53	276	5,273	4.1	216	5,056
1913	....	....	....	....	....	....	4,832	4.1	198	5,240
1914	....	....	....	....	....	....	....	....	....	6,381
Average[1]	5,240	4.89	256	6,284	4.48	281	5,348	4.1	207	5,032
Average[2]	5,240	4.89	256	6,536	4.48	293	5,053	4.1	207	5,142

[1] Average of all years for which reports are given.
[2] Average years for which complete and comparable costs are available. These are the average production figures used in determining cost per unit in Table XI. The years included in this average are: Wisconsin farm, 1909–1912; Michigan farm, 1910–1912; Pennsylvania farm, 1912 and 1913; North Carolina farm, 1911–1913.

NET COST PER UNIT OF PRODUCT.

Table XI shows the net yearly cost that is chargeable to the production of milk and the cost per unit of 100 pounds of milk, per 40-quart can, and per quart. The cost per pound of butter fat, not deducting credits for skim milk and buttermilk, is also shown. The cost per 100 pounds of milk varies from $1.52 to $2.16, and the cost of other units of measure vary in like proportions. The pounds of milk are changed to quarts by dividing by 2.15. The gross feed cost on the Wisconsin farm is 1.59 cents, as compared with 2.43 cents per quart of milk on the North Carolina farm.

The relative proportion of each item of cost in the production of 100 pounds of milk, which is equally applicable to any other unit used in measuring the product of the dairy, is illustrated by fig. 4.

These charts are constructed on the basis of cost per cow after deducting, pro rata, the credit for value of manure, calf, etc.

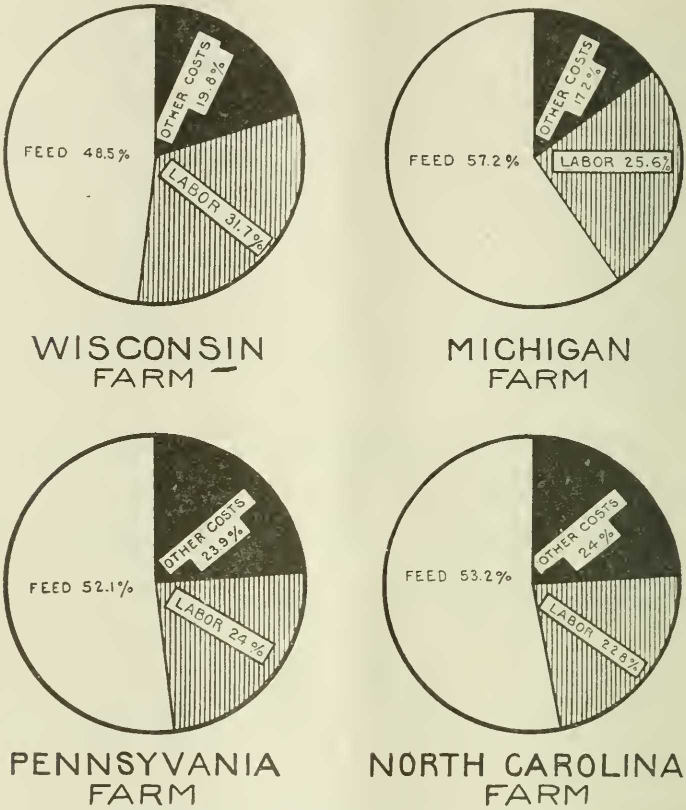

FIG. 4.—Relative importance of each item in the cost of producing 100 pounds of milk on each of the four farms.

The four dairy herds in question are well managed, and it is safe to say the production per cow for each is above the average of the dairy herds of its community.

TABLE XI.—*Yearly cost per cow, production per cow, and cost per unit of production on each of the four farms.*

Farm.	Average per cow.					Cost per unit of product.			
				Yield.		Milk.			Butter fat.
	Total cost.	Credit other than milk.	Net cost.	Milk.	Butter fat.	100 pounds.	40-quart can.	Quart.	Pound.
				Pounds.	*Pounds.*			*Cents.*	*Cents.*
Wisconsin[1]	$101.61	$21.75	$79.86	5,240	256	$1.52	$1.31	3.28	31.2
Michigan	125.45	20.33	105.12	6,536	293	1.61	1.38	3.46	35.9
Pennsylvania	103.12	12.27	90.85	5,053	207	1.80	1.55	3.87	49.8
North Carolina	127.76	16.81	110.95	5,142	....	2.16	1.86	4.64	....

[1] The data compiled in this table are for the same years as those averaged in Table I.

It is not within the scope of this bulletin to discuss the profits and losses in the production of milk on these four farms. However, it may add interest to give the average receipts per cow from the sale of milk during the period covered by records, as shown in Table XII. Comparing the figures of Tables XI and XII, it will be seen that, on the average for the entire period, each of these farms made a profit from their dairies.

TABLE XII.—*Average receipts per cow from sale of dairy products on each of the four farms.*

Year.	Wisconsin farm.	Michigan farm.	Pennsylvania farm.	North Carolina farm.
1909	$88.47	$97.63		
1910	82.72	123.72		
1911	79.08	101.55		
1912	80.92	120.92	$96.77	$136.00
1913			113.45	130.76
Average	81.40	110.96	105.11	133.38

DATA FROM OTHER SOURCES.

In connection with this same problem, other investigators have published certain results. The publications from the New Hampshire, Massachusetts, and Connecticut[1] (Storrs) agricultural experiment stations give the cost per cow in sufficient detail, so that the items may be studied under the groups shown in Table I.

The relation of each item of cost to the total cost of keeping a cow as reported by the three New England experiment stations is given in Table XIII.

TABLE XIII.—*Relative importance of factors which make up the cost of producing milk as reported by three New England agricultural experiment stations.*[2]

Item.	Cost per cow per year.					
	Connecticut.[3]		Massachusetts.[3]		New Hampshire.[3]	
	Actual cost.	Per cent.	Actual cost.	Per cent.	Actual cost.	Per cent.
Feed	$85.02	56.7	$89.24	54.9	$73.03	49.4
Labor:						
Cows and dairy	33.60	22.4	35.00	21.6	32.33	21.8
Marketing					7.18	4.9
Use of buildings	3.95	2.6	7.50	4.6	9.05	6.1
Use of equipment			1.15	.7	.53	.4
Use of bull	3.00	2.0	4.00	2.5	3.79	2.6
Interest	3.75	2.5	5.25	3.2	4.55	3.1
Depreciation	13.00	8.7	11.25	6.9	8.83	6.0
Miscellaneous	7.70	5.1	9.00	5.6	8.44	5.7
Total	150.02	100.0	162.39	100.0	147.73	100.0
Credits:						
Manure and calf	15.00		17.00		18.00	
Average pounds milk per cow	6,378		6,036		6,463	

[1] See *a*, *b*, and *c* in "Literature Cited," p. 34.
[2] Other agricultural experiment stations have publications showing the cost of keeping a cow and the cost of producing milk, but the data are not presented in sufficient detail to be included in this table.
[3] See *a*, *b*, and *c*, p. 34.

The data from Massachusetts and Connecticut are results from the experiment station herds, while the data from New Hampshire are a compilation from all the herds of the Lyndeboro Cow Testing Association. These data differ in some respects from that procured from complete cost records. However, considering the difference of conditions and methods under which the herds were handled, the results from all these sources closely coincide.

In each case the feed cost has been determined from actual records. Although many of the items other than feed were determined from estimates for the New England herds, they compare closely with the same items from actual records. By comparing Tables I and XIII, it will be seen that the total cost of keeping a cow, both on the two experiment station farms and in the cow-testing association, is somewhat higher than on the four farms discussed above. However, in terms of the proportion which feed, labor, and other costs bear to total cost, they check closely. In the feeding of a grain ration the entire year the Michigan herd is handled similarly to the Connecticut and Massachusetts experiment station herds, and the cost of feed in these three herds is 57.2, 56.7, and 55 per cent, respectively, of the total cost of keeping a cow.

The New Hampshire figures were compiled from farm herds where pasture was influential in reducing the feed cost. In this respect these herds are not unlike the Wisconsin, Pennsylvania, and North Carolina herds, and the feed is about one-half of the total cost.

The cost for labor, as shown by the New England records, is a little higher than on the four farms; however, the per cent of the total cost is a trifle lower. The cow-testing association record shows the total labor to be slightly more than one-fourth of the total cost, whereas at the experiment stations, where no marketing is included, the labor is less than one-fourth.

The individual items other than feed and labor show greater divergencies, but considering them as a whole they compare fairly well. Some of the charges included in the individual items are not the same. For instance, "Overhead" is entirely omitted from the New England records, and a part of equipment-cost charges are either omitted or were too closely linked with other items to be separated.

The item "Miscellaneous," as shown in Table XIII, takes care of a share of what might otherwise be called overhead. It also includes in each case a charge of about $5 per cow for bedding. This item of expense may show up on many herds, but was so small on the four farms that it was included in the feed cost. Its consideration here tends to offset the items not given separately on the New England records.

DISCUSSION OF RESULTS.

In taking up the consideration of the data from the four farms and of their practical application to the production of milk throughout the country, it is essential to note that milk and other dairy products are furnished by farms that may be divided into two general types. One type is the specialized dairy farm, where the source of income is primarily from dairy products. The whole farm organization is built around the dairy enterprise; labor is hired primarily to work on the herd; crops are grown for consumption by the herd; and the income of the owner is determined wholly by the efficiency with which the dairy is handled. Farms of this type are comparatively few in number and are found mostly in regions near large cities where there is a good demand for market milk. All four of these farms tend toward this specialized type. The Michigan farm is the most intensive. The second type, the general farm, is found everywhere throughout the country. The herd usually numbers from a few cows to 15 or 20, but the keeping of cows is only a part of the general farm business. The farmer may sell some other kind of live stock, farm crops, or fruit. While the receipts from cows contribute to his income, his success or failure financially is but partially dependent upon the efficiency with which he cares for his cows. On the Pennsylvania and North Carolina farms considerable income is derived from the sale of other products.

THE FEED PROBLEM.

The results of this study indicate that on farms where cows depend on pasture, with little or no grain during the pasture season, the cost of feed is approximately one-half the total cost of keeping the cow. On farms where more intensive dairying is practiced, pasture is limited, and a grain ration is fed throughout the year, the feed is nearer 60 per cent of the cost. These facts further emphasize the point that, "with few exceptions, the feed bills are the real burden to the dairyman."[1] Naturally, then, the producer of dairy products who would increase his profits by economizing in cost of production should first consider this largest item of cost. In many cases economy may result from an actual reduction of feed cost per cow, whereas, in other cases it may be necessary to increase the feed bills to insure the greatest profits. The quantity of feed supplied each cow should not be below the quantity she requires for the most efficient production. The real economic problem is to supply a palatable ration which contains the essential constituents in sufficient quantity at the lowest cost. (See fig. 5.) The fundamental principles of compounding a ration on the basis of nutrition have been determined by extensive experimental studies.

[1] Feeds and Feeding, Henry and Morrison.

The question of providing feed is different on each of the two general types of farms that maintain dairy cows. Just how near the specialized dairyman should come to growing all the feed required by his dairy herd is a question of individual business management.[1] One man may find it most profitable to grow all the feed required, while another may increase his profits by supplementing the income from cows with crop sales and purchase a part of the feed. In a few localities in the United States crops may be selected that will not only yield a product for which there is ready sale at good prices, but also leave on the farm much feedable material. Sweet corn is an example of this type.

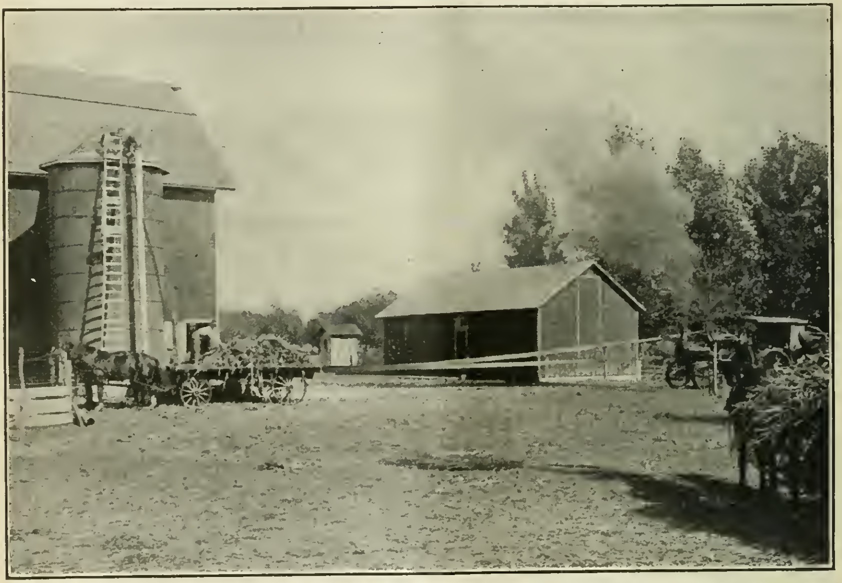

FIG. 5.—A silo is usually a profitable investment in connection with the feeding of dairy cows.

As a matter of fact, there was a wide variation on the four farms studied as to the practice of growing or buying the feed. On the Wisconsin farm concentrates were purchased in addition to feeding all the crops raised. The practice on the Michigan farm was similar in this respect to the Wisconsin farm, except that more feed was purchased, owing to the absence of sufficient pasture. On the other hand, the practice on the Pennsylvania farm was to sell wheat and timothy and to buy some concentrates. No roughage was sold from the North Carolina farm, where cotton and tobacco were important cash crops. The dairy cow ration was completed with purchased feeds.

[1] See *d*, p. 34.

Where this practice of supplementing the dairy business with the production of cash crops is feasible, it is profitable for the dairyman to sell some crops and purchase concentrates. If, by the growing of a cash crop, it is possible from the net receipts of one acre to buy a quantity of concentrates equivalent to that which could be raised on 1½ or 2 acres, it would be folly to grow the concentrates. In other words, this class of feed should not be grown when it is possible to raise some other crop at a greater profit without seriously affecting the labor required on the farm.

The majority of the cows in the United States are found on the general or diversified farms. The herds on these farms are smaller than on the specialized dairy farm, but there are so many farms of this class that they produce the greater part of our dairy products, aside from market milk. Owing to the meagerness of the receipts per cow on many farms of this type, it is safe to assume that the complete cost of the product is often more than the actual cash receipts. Nevertheless, cows are kept on these farms, and have been kept for years. This would not be true if, on the average, their owners did not feel that their farms produced greater incomes with these cows than they could without them.

The principal reason that this class of farmers can continue to produce dairy products at an apparent loss, as shown by cost accounts, is that in connection with the profitable production and marketing of crops the cows consume by-products and low-grade materials, and also use land as pasture that otherwise would be wasted. Moreover, the manure recovered is beneficial in further crop production. The quantity of such feedable materials that otherwise might largely be wasted if not fed to live stock, is in great measure determined by the location of the farm in reference to markets. That is, what may be a by-product on a farm several miles from a railroad station or a city market may be a readily salable product on a farm close to market. Different cropping systems yield different quantities of these feedable materials. For example, a cropping system of potatoes, beans, wheat, and hay will yield less feedable by-products than corn, oats, wheat, and hay. Regardless of the quantity of these materials produced on diversified farms, the fact is that unless such materials are consumed and made into manure by live stock such would, in many cases, be a total waste. In practice, therefore, it is not a question of charging this feed on such farms at $3, or $5 or $7 per ton, as must of course be done in cost accounting, but of utilizing otherwise valueless material in such a way that it will return something. The problem of these farmers is to make use of this roughage on the farm and to convert it into a product which has a ready market. These farmers have found that one of the best ways of doing this is by feeding it to dairy cows.

The fact must not be overlooked that while for clearness in discussion dairy farms have been divided into the two general types, in actual conditions there are farms where dairying is found in every degree of intensity. As the farm becomes more specialized in character the feeding practice must be changed to conform with the individual conditions. Each farmer or dairyman must formulate his own ration, but in so doing it is necessary that he first learn what his feeding problem really is, and having done this, decide upon a feeding practice which will produce milk so that the dairy will contribute to the maximum farm profit.

THE LABOR PROBLEM.

The data presented above show that the labor item is second to feed in importance, and is approximately one-fourth of the total expense of keeping a cow. With the increased demands for cleaner dairy products it is reasonable to expect that in many cases more work will be necessary, both in caring for the cows and for the milk. This may also require more efficient labor on many farms and perhaps higher wages. In attempting to reduce the cost for labor it must be remembered that a cow responds to good treatment, and the efficiency of labor has a close relationship to the profitableness of the dairy business. This point is emphasized by the Minnesota Experiment Station [1] in the following statement: "We know of many instances where the best of the dairy cows were kept and where good methods of feeding were practiced; and still results fell far short of what might reasonably be expected, simply because the animals did not receive the kindly treatment which is so essential to a cow giving much milk for a long period."

On specialized dairy farms where hand milking is practiced a number of laborers are hired primarily for work in the dairy. The dairy enterprise seldom provides work to keep the men profitably employed throughout the day, largely because more men are required to milk than are needed to do the other dairy work. It may be expected that the use of milking machines on these farms will change this labor requirement to some extent. Nevertheless, the same general principle holds good, that he who would economize on this expense for labor must provide other work during that part of the day when labor is not needed in the dairy. For this reason the growing of some field crops is always advisable. On each of the four farms from which data have been presented all labor used on the farms has been charged to the various enterprises at a uniform rate per hour Inasmuch as this labor was primarily employed for the dairy, it might seem logical to charge the portion thus used at a higher rate and to charge the labor used in the production of crops and on other farm work at a lower rate. At the same time, labor on the more general

[1] See *e*, p. 34.

farm is hired primarily for the production of crops, and the use of this labor in the care of live stock supplements the crop labor, making it seem equally logical to charge crops at a high rate and the live stock at a low rate per hour. But no distinction of this kind has been made in this bulletin.

The cost of caring for the dairy cow on the more general farm is low. Extra workmen are seldom hired for this purpose. During the crop-growing season the cows are cared for in addition to the regular day's work in the field. Quite often the women and children do the milking, especially at times when crop work is heavy and the men are required to work late. Again, during the winter months there is little or no productive field work, and the dairy cows furnish

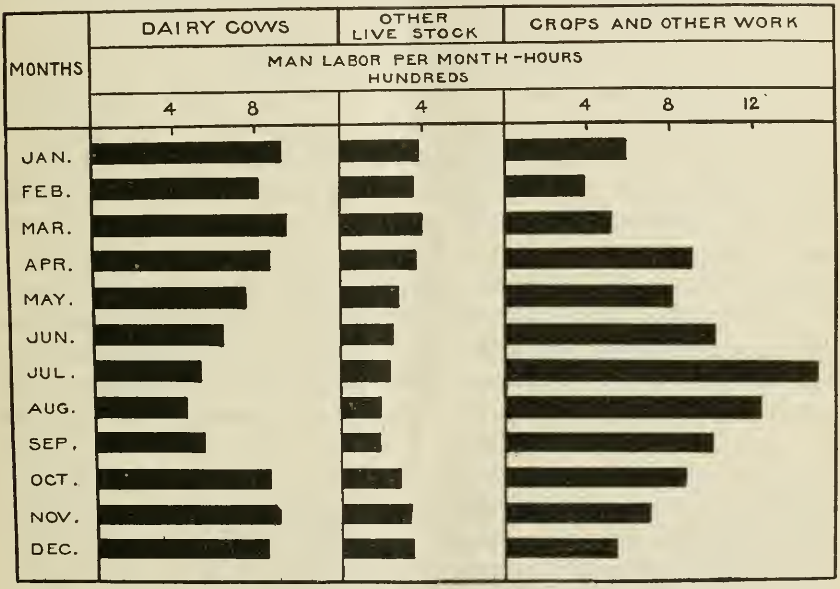

FIG. 6.—Distribution of man labor by months on the dairy enterprise as compared with the hours used by other live stock and that available for growing crops and other work on the Wisconsin farm, 1911.

employment for labor that would otherwise be idle. As a result of these conditions the actual cash outlay for labor is frequently no greater with a few cows on the farm than it would be without them. On these general farms, the same principle which is true for the feed is also true for labor; that is, it is not a question of getting 15 or 20 cents per hour for this labor, but of getting something, and in so doing increase the income of the farm business.

Figure 6 is a chart showing for the Wisconsin farm in 1911 the distribution of man labor by months on the dairy enterprise, as compared with the hours devoted to the care of other live stock and those devoted to growing crops and to other necessary work. This shows that the most labor on the dairy comes during the period from October to April. The system of winter dairying practiced on this farm provides for the maximum amount of labor available for other purposes during the period when most labor can be used in the production of crops. This also illustrates the fact that crop-production work does not provide full employment for labor throughout the year. On general farms the keeping of a certain number of cows can be made to supplement the crop labor and thus provide profitable employment all the year.

It is far better to fill in this winter time thus, even though the wages returned are low, than not to utilize it at all and receive nothing. This is another reason why cows are maintained on general farms where cost records, charging labor at full rates, show the returns to be less than the cost. Within certain limits, they may add to the profits of the farm business even at an apparent loss.

THE PROBLEM OF DEPRECIATION.

Depreciation is a matter of little importance to the owner of a herd of poor cows. A poor dairy cow is ordinarily worth almost as much for beef as for dairy purposes and sometimes more. However, this item is of serious importance to the owner of high-priced dairy cows, for his worn-out cows are worth no more for beef than scrubs, and perhaps not so much. It is a known fact that annual depreciation increases with an increase in the value of the cow as a milk producer. The amount of depreciation may vary greatly from year to year on the same herd and with different methods of management. On the four farms studied it is comparatively low, whereas the literature now published indicates that on the average a much larger charge may be expected than was found on these farms. The Massachusetts Agricultural Experiment Station[1] estimates that with cows having an average value of $75 the annual depreciation per cow will amount to $11.25. The Connecticut (Storrs) Agricultural Experiment Station[1] found that the cost of maintaining the standard of the herd for a period of five years was $13.26 per cow per year. The records of a cow-testing association in New Hampshire[1] show the average life of a cow to be a little over four years. Calculations made from the dairy herd records published by the Nebraska Agricultural Experiment Station[1] indicate that in herds where the poor cows are carefully culled out on the basis of production records practically one-third are discarded each year, thus making the average life in the herd not far from three years.[2]

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[1] See *b*, *c*, *a*, and *f*, p. 34.

[2] From the records published by the Nebraska Agricultural Experiment Station, Bulletin 139, it was found that during the period of 14 years 310 yearly records were procured from 110 different cows, which is an average of 2.82 years per cow. From the 71 cows which entered the herd and were later sold 198 yearly records were obtained. This is equivalent to an average productive life in the herd of 2.79 years. Of these 71 cows only 16 were kept five years or more, of which nine were retained five years, four six years, one seven years, one nine years, and one 12 years. From the 38 cows in the herd at the close of the period 110 yearly records were procured, which is an average of 2.90 years per cow. Of these 38 cows 12 had completed but one year, while 11 had been in the herd four years or more.

In the recently-published results of a farm-management survey [1] it is shown that on 378 farms in Chester County, Pa., operated by owners, the length of time the average cow remains in these herds is 4.34 years. The yearly charge for depreciation on these farms is very nearly $6.70 per cow. For 300 farms in Lenawee County, Mich., the average cow remains in the herds 4.52 years, and the yearly charge for depreciation is very nearly $2.14.[2]

With cows of good quality the amount of depreciation may be kept low by judicious selling. The heifers which are culled out can usually be sold without serious loss. The cows not discarded the first year usually increase in value up to a certain age and then decrease in value rapidly. Some dairymen keep their depreciation item to a minimum by placing the cow on the market for dairy purposes just before this decrease comes. However, this is a profitable practice only from the standpoint of the seller, for it must be remembered that the buyer must always stand the depreciation which the seller has evaded.

BUILDINGS, EQUIPMENT, ETC.

In erecting buildings for the dairy herd profit often depends on discretion. It is not unusual to find places where, if the cows paid interest on the money invested in dairy buildings, it would be impossible for them to pay for anything else. From an economic standpoint an investment in buildings beyond that required to provide adequately for comfort, convenience, and sanitation is a personal matter with the owner. While cows kept in palacelike buildings are perhaps more fortunate, it is doubtful whether they are

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[1] See *g*, p. 34.

[2] U. S. Department of Agriculture, Bull. 341, pp. 93–95. In this publication the rate of depreciation on dairy cows does not represent the annual rate at which an animal deteriorates after it passes its prime, for as the calculation is made the depreciation of such animals is in part cancelled by the increase in value of animals before they reach their prime. The method of calculation is the same as outlined on p. 13 of this bulletin, with proper adjustment being made for the increase or decrease of the selling price of cows during the year. But the rate obtained does represent approximately the average charge which must be made for depreciation in determining the cost of maintaining the dairy herd.

For 378 farms in the Chester County, Pa., area the average annual loss on dairy cows from depreciation in value was 11.82 per cent of the average of the inventory values for the beginning and the end of the year. A similar calculation for 300 farms in Lenawee County, Mich., showed a corresponding rate of 4.07 per cent. The authors analyze these figures thus:

"In making these calculations it is assumed that it costs as much on the average to raise a dairy cow as the average price at which cows are purchased in the respective localities. This may be in error, but even if the cost be considerably less, the results would not vary greatly from those given, because of the relatively small proportion of cows raised, especially in the Pennsylvania area.

"The marked difference in the rate of depreciation of dairy cows in the two areas is due mainly to the difference in the prices at which cows are bought and sold in the two localities. In the Michigan locality the dairy farmers pay on the average $48.48 for cows and sell their discards for $42, a difference of only $6.48, whereas the dairy farmers in the Pennsylvania locality pay an average price of $63.84 and sell for $37.36, a difference of $26.48. Thus the Pennsylvania farmer loses $20 more per cow bought and sold than does the Michigan farmer. This accounts for the much larger annual charge for depreciation on the Pennsylvania farms.

"In the Chester County area the farmers on the average raise 37 per cent of their cows and buy the remainder. In the Michigan locality they raise 57 per cent. The proportion of the average herd discarded yearly is 23 per cent in Pennsylvania and 21.6 per cent in Michigan. The average length of time the average cow remains in these herds is therefore 4.34 years (=100/23) in Pennsylvania area and 4.52 years in Michigan area. The yearly percentage of deaths in the herds was 1.69 for Pennsylvania and 1.31 for Michigan."

more productive than those housed in adequate quarters for which they are able to pay a reasonable rental charge. On the other hand, it is not uncommon to find cows so poorly housed that it is not possible for them to make a profitable yield. The location of the farm with reference to markets, the degree of cleanliness desired, as well as the size and economic productivity of the herd, are factors to be considered in relation to an economic investment in buildings. Buildings which would be desirable and economical on a dairy farm near the city, where certified milk finds a ready market, would hardly be adapted to the use of a herd of the same size where the only market is a local cheese factory or creamery buying on the butter-fat basis. Neither would a herd having an average production per cow of 4,000 pounds of milk justify the same investment in buildings and equipment as one having an average of more than 6,000 pounds per cow.

The investment per cow in dairy buildings on the four farms discussed in previous pages is moderate, being $84 on the Wisconsin farm, $50 on the Michigan, $83 on the Pennsylvania, and $80 on the North Carolina farm. A larger herd is one reason for the lower investment per cow on the Michigan farm. Other things being equal, the larger the herd that can be accommodated with a given investment the lower the amount per cow.

The question of an economic investment in equipment and supplies is closely related to that of buildings, and the same general principles hold true in both cases. Expensive milk coolers and ice supplies, which may be absolutely necessary in the production of high-grade milk for a special market, might be both unnecessary and extravagant in the production of cream to be sold on the butter-fat basis. In other words, expenses for buildings, equipment, and supplies should never be so high as to make it difficult or impossible to realize a reasonable dividend on the capital invested in the herd.

The other items in the total cost of milk, including interest, expense for use of bull, miscellaneous items, and overhead, depend quite largely upon the efficiency of the management of the dairy herd and farm business. The charge of interest on money invested in cows is in direct proportion to the value of the cows.

The charge per cow for use of bull is largely in proportion to the value of the bull and the number of cows in the herd. In attempting to raise the general productivity of the herd through the selection and raising of heifers from the best cows, the influence of the quality of the bull in the herd is felt for years, and, within reasonable limits, any additional cost because of his quality will be far more than offset by the increased value of the heifer calves. Furthermore, there is a good market for calves of good breeding, and those not needed in the herd can be sold for much better prices than those sired by a scrub bull.

The amount of the charges for miscellaneous items and overhead varies with the size, type of the business, and efficiency of the management.

In view of the fact that the assumption frequently has been made that the value of manure and calf will offset the costs other than feed, it is of interest to note the relation of these credits to the total cost of keeping a cow on the four farms. This relationship is shown in figure 3, page 15, data for which are taken from Tables I and IX. On these farms the credits for these items do not equal the cost items other than feed and labor combined and range from 25 to 29 per cent of items other than feed.

RELATION OF INDIVIDUAL COW TO COST OF PRODUCTION.

In the previous paragraphs the discussion of the data has related to the dairy herd as a unit. By referring to Tables XI and XII, it may be seen that each of the four farms shows a net profit per cow on this basis. The data from each of these farms were also obtained in sufficient detail to permit a study of the individual cows in relation to profitableness of production. Table XIV shows the relation of milk production and the cost per cow to the cost per 100 pounds of milk, based on data from 443 complete yearly records on four farms. The records were divided into production groups on the basis of even thousands of pounds per cow, beginning with those producing 3,000 pounds and less and ending with those having a production of over 8,000 pounds. The average production of 16 cows in the first group was 2,349 pounds, costing $83.90, of which $43.93 was for feed. The average production of 111 cows in the 5,001 to 6,000-pound group was 5,450 pounds, costing $114.42, of which $59.91 was for feed. The average production of 36 cows in the 8,000 group and over was 9,049 pounds, costing $153.65, of which $80.45 was for feed.

TABLE XIV.—*Relation of milk production and the cost per cow to the cost per 100 pounds of milk, based on data from 443 complete yearly records on four farms.*[1]

Basis of classification.	Number of cows.	Production.	Average per cow per year.			Average per 100 pounds of milk.	
			Feed cost.	Other cost.	Total cost.	Feed cost.	Total cost.
Production of milk per cow:		*Pounds.*					
3,000 pounds and under	16	2,349	$43.93	$39.97	$83.90	$1.87	$3.57
3,001 to 4,000	33	3,648	49.47	45.01	94.48	1.36	2.59
4,001 to 5,000	78	4,596.1	55.00	50.04	105.04	1.20	2.29
5,001 to 6,000	111	5,450	59.91	54.51	114.42	1.10	2.10
6,001 to 7,000	109	6,445	62.85	57.18	120.03	.93	1.86
7,001 to 8,000	60	7,513.5	70.38	64.04	134.42	.94	1.79
Over 8,000	36	9,049	80.45	73.20	153.65	.89	1.70

[1] The cost for individual cows on each farm was determined as follows: The item of feed was obtained from individual records; the items of labor, use of buildings, use of equipment, use of bull, and miscellaneous items for each year were divided pro rata on the basis of numbers; the items of interest and depreciation were obtained for individuals from inventory valuations; the item of overhead expenses was distributed on the basis of total cost for labor and materials the same as explained on p. 14.

The data in table XIV show the relation between the cost of keeping cows of varying milk yield and the cost of the milk. The same data are also shown in graphic form in figure 7. It will be noticed that as milk yield increases there is also an increase in the feed cost and in other cost items, but not in the same proportion. Cows yielding less than 3,000 pounds produced milk at a cost of $3.57 per hundred. Those yielding 5,001 to 6,000 pounds produced it at $2.10 per hundred. Those yielding over 8,000 pounds produced it at $1.70 per hundred. It is apparent, in so far as conclusions can be drawn from the records of these four herds, that the cost of producing milk from low-yielding cows is very high and that this cost gradually decreases with better cows. This decrease in cost is much greater

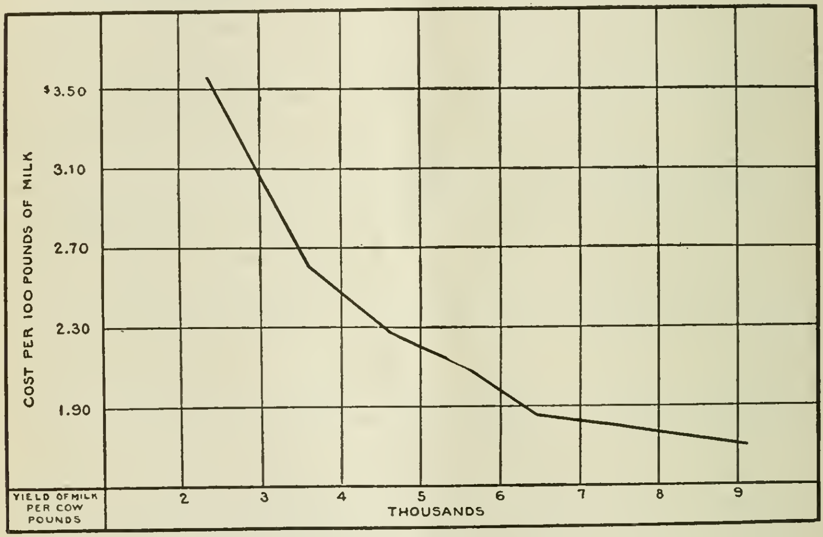

FIG. 7.—Relation between annual yield per cow and cost per 100 pounds of milk on the four farms.

between the very poor cow and the cow of medium quality than it is between the medium cow and the good cow. For instance, milk from cows producing from 3,001 to 4,000 pounds of milk per year costs 98 cents less per hundred pounds than milk from cows producing less than 3,000 pounds, while milk from cows producing over 8,000 pounds costs but 9 cents less per hundred than milk from cows producing from 7,001 to 8,000 pounds. The four herds in question were of mixed breeds, with Jerseys predominating. In the case of higher producing herds, or if returns were figured in terms of butter fat rather than pounds of milk, different results might be expected. Often cows of only moderate production in pounds of milk yield good returns by reason of a high percentage of butterfat.

TABLE XV.— *Yearly savings in cost of milk production effected on the four farms by displacing low-yielding cows with higher-yielding cows, figured on the basis of data presented in Table XIV.*

(*a*) DISPLACING A COW PRODUCING 3,000 POUNDS OR LESS.

	Basis of classification (production of milk per cow).	Average production.	Cost per 100 pounds.	Cost of 2,349 pounds.	Saving yearly in cost per cow.
	Pounds.	*Pounds.*			
Performance of cow displaced	*3,000* or less.	*2,349.0*	*$3.57*	*$83.90*	....
Comparative performance of better cows	3,001 to 4,000	3,648.0	2.59	60.84	$23.06
	4,001 to 5,000	4,596.1	2.29	53.79	30.11
	5,001 to 6,000	5,450.0	2.10	49.33	34.47
	6,001 to 7,000	6,445.0	1.86	43.69	40.21
	7,001 to 8,000	7,513.5	1.79	42.05	41.85
	Over 8,000	9,049.0	1.70	39.93	43.97

(*b*) DISPLACING A COW PRODUCING 3,001 TO 4,000 POUNDS.

				Cost of 3,648 pounds.	
Performance of cow displaced	*3,001* to *4,000*	*3,648.0*	*$2.59*	*$94.48*	....
Comparative performance of better cows	4,001 to 5,000	4,596.1	2.29	83.54	$10.94
	5,001 to 6,000	5,450.0	2.10	76.61	17.87
	6,001 to 7,000	6,445.0	1.86	67.85	26.63
	7,001 to 8,000	7,513.5	1.79	65.30	29.18
	Over 8,000	9,049.0	1.70	62.02	32.46

(*c*) DISPLACING A COW PRODUCING 4,001 TO 5,000 POUNDS.

				Cost of 4,596.1 pounds.	
Performance of cow displaced	*4,001* to *5,000*	*4,596.1*	*$2.29*	*$105.04*	....
Comparative performance of better cows	5,001 to 6,000	5,450.0	2.10	96.52	$8.52
	6,001 to 7,000	6,445.0	1.86	85.49	19.55
	7,001 to 8,000	7,513.5	1.79	82.27	22.77
	Over 8,000	9,049.0	1.70	78.13	26.91

(*d*) DISPLACING A COW PRODUCING 5,001 TO 6,000 POUNDS.

				Cost of 5,450 pounds.	
Performance of cow displaced	*5,001* to *6,000*	*5,450.0*	*$2.10*	*$114.42*	....
Comparative performace of better cows	6,001 to 7,000	6,445.0	1.86	101.37	$13.05
	7,001 to 8,000	7,513.5	1.79	97.56	16.86
	Over 8,000	9,049.0	1.70	92.65	21.77

(*e*) DISPLACING A COW PRODUCING 6,001 TO 7,000 POUNDS.

				Cost of 6,445 pounds.	
Performance of cow displaced	*6,001* to *7,000*	*6,445.0*	*$1.86*	*$120.03*	....
Comparative performance of better cows	7,001 to 8,000	7,513.5	1.79	115.37	$4.66
	Over 8,000	9,049.0	1.70	109.57	10.46

From the standpoint of economic milk production it would seem that the easiest step in the building up of a poor dairy herd is relatively the most profitable. Certainly the step from the poor cow to the cow of medium capacity is the one which promises the largest dividends on a modest expenditure of money and effort. In this connection the reader should study Table XV, which shows the gains resulting from progressively displacing a low-yielding cow with a better one. In these particular herds for every 7,000-pound cow that displaced a 3,000-pound cow there was an annual gain of over $40, while for every 8,000-pound cow which displaced a 7,000-pound cow there was a gain of about $5. From the foregoing it will be seen that the dairyman with limited capital need not be discouraged, as it is practicable for him to build up a highly productive and profitable herd.

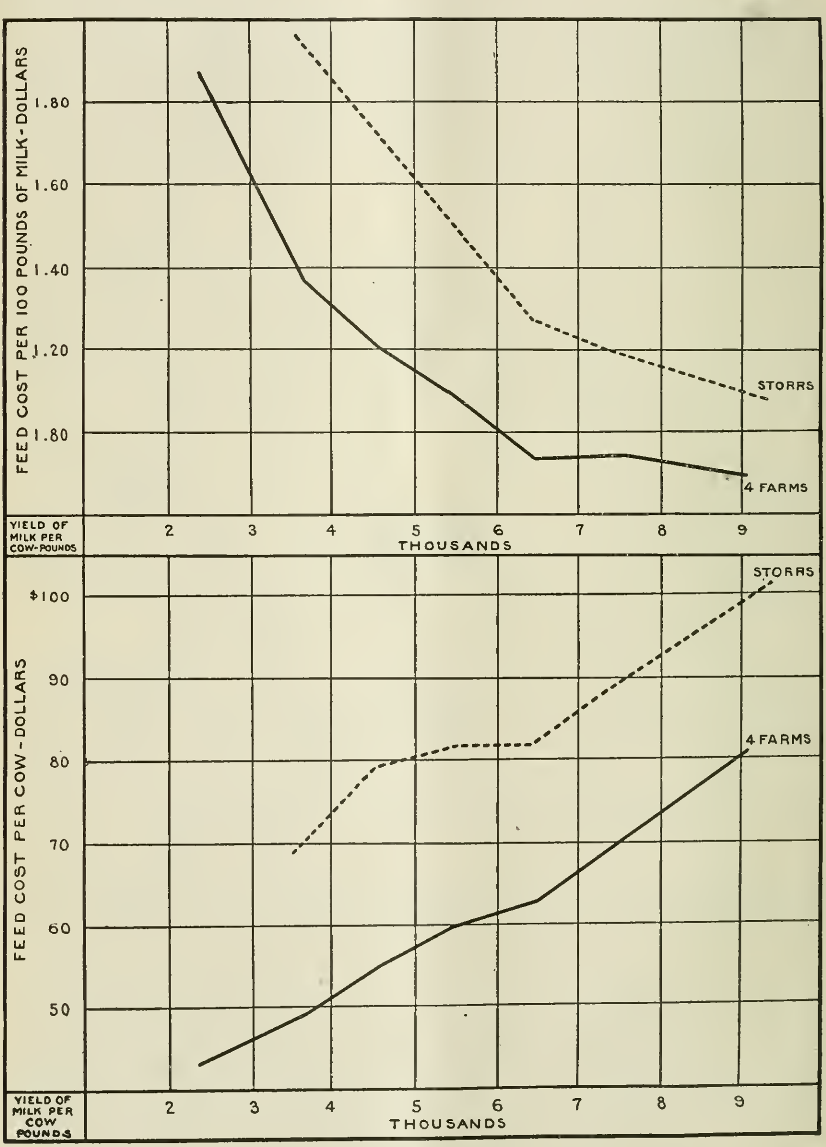

FIG. 8.—Data from the four farms and from Connecticut (Storrs) Agricultural Experiment Station. Upper: Relation between feed cost per 100 pounds of milk and production per cow. Lower: Relation between feed cost per cow and production per cow.

This result is in keeping with common experience both with animals and crops, namely, that the greatest savings are achieved in changing from the very poorest animals or crops to those of medium production or better.[1]

Most of the cows producing less than 4,000 pounds in these herds were heifers. This illustrates a factor of economic importance connected with maintaining the standard of the herd by the introduction of heifers. Normally, heifers do not produce as much as mature cows. Moreover, many heifers, even though carefully selected, do not measure up to expectations and must be discarded. As a result, even in the most efficiently managed herds, the production from heifers is comparatively low, and the cost per unit of product relatively high. In connection with the discussion of this topic it is of interest to note the relative feed cost of cows on these four farms according to their milk production and to compare the same groups in their relation to the feed cost per 100 pounds of milk. These comparisons are made in graphic form in figure 8, which also includes curves constructed from records published by the Connecticut (Storrs) Agricultural Experiment Station.[2] There were no cows in the station herd that produced less than 3,000 pounds. Owing to higher prices, the actual feed cost per cow and per unit of product was greater for the cows of each group in the station herd. The data from the four farms show that it costs more to keep a cow that gives a high yield of milk than one giving a low yield. However, within the limits of production shown by these cows, the profits from the high-producing animals are greater, because the increased cost of keeping a cow is not in proportion to increase in yield. This results in a lower unit cost for the product and a greater margin of profit, both per unit and per cow. These data emphazise the fact that the quality of the individual cow is a highly important factor in the cost per unit of product.

SUMMARY.

While the results derived from the cost records from the four farms in question may be said to be strictly applicable only to the farms upon which the studies were made, nevertheless they are representative of certain types of dairying, and the fundamental facts developed in studying them will be of considerable practical value to all milk producers and especially valuable to those operating under similar conditions.

From the information on these four farms there appears to be a fairly uniform relationship between various items entering into the cost of milk production according to the type of dairying followed.

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[1] "It is both easier and more profitable to increase * * * a small product per cow than a large one."—Dept. Bul. 341.

[2] See c, p. 34.

The feed cost on these farms seems to approximate 50 per cent of the total cost of keeping a cow where the cows depended on pasture with little or no grain during the pasture season; whereas, feed cost approximated 60 per cent on the farms where the pasture is limited and a grain ration is fed throughout the year.

Labor, the second important item in the cost of producing milk, amounted to approximately one-fourth of the total cost of keeping a cow.

All other items, including charges for shelter, use of equipment, use of bull, interest, depreciation, miscellaneous supplies, and a share of overhead expenses, amounted to approximately one-fourth the total cost of keeping a cow. The credits other than milk, including the value of calf, manure, and minor items, did not equal the miscellaneous costs other than feed and labor.

Though it cost more to keep a cow that gives a high yield than one giving a low yield, the unit cost of the milk produced fell as the yield per cow rose. This decrease in the cost of milk per pound was much greater in the step from the poor cow to the cow of fair quality than in the step from the fairly efficient cow to the good cow or to the exceptional cow. Thus, from the standpoint of economic milk production, it appears that the first step in building up a poor dairy herd (that is, replacing scrubs with grades) is not merely the easiest step but also the one which promises the most for a given expenditure of money and labor.

The actual cost of keeping the cows varied from year to year on the different farms as well as on the same farm, yet the ratio between each item and the total cost was apparently quite uniform where a similar method of management was followed.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 502

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C. PROFESSIONAL PAPER April 23, 1917

THE DRAINAGE OF IRRIGATED SHALE LAND

By

DALTON G. MILLER, Senior Drainage Engineer, and
L. T. JESSUP, Junior Drainage Engineer

CONTENTS

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THE DRAINAGE OF IRRIGATED SHALE LAND.[1]

By DALTON G. MILLER, *Senior Drainage Engineer*, and L. T. JESSUP, *Junior Drainage Engineer.*

CONTENTS.

INTRODUCTION.

Drainage is now recognized as one of the most important problems confronting the farmers of irrigated lands. Drainage methods in the arid regions differ from those in the humid sections, and even with respect to arid land different methods must be used for different types of land. One of the frequently occurring types that require special treatment is the so-called shale land, by which term is meant those lands that are immediately underlain by shale which may or may not outcrop and in which the soil is made up largely of disintegrated shale. Areas of this type occur in all of the Rocky Mountain States and in some of those immediately adjoining.

In spite of the fact that shale is classed among the less pervious formations, it becomes an important factor in the movement of underground water in those areas where uplifts and displacements have occurred. Investigations by this department have shown that in those sections which have underlying shale near the surface there is a close relation between the shale and the areas of seepage. This relation depends more or less on the topography of the underlying shale,

[1] This bulletin contains information on the drainage of those irrigated lands of the Rocky Mountain States that are underlain by shale.

ACKNOWLEDGMENTS.—The soil analyses presented in this bulletin were made in the laboratory of the Bureau of Soils, U. S. Department of Agriculture. The analyses of the water samples were made in the water laboratory of the Bureau of Chemistry, U. S. Department of Agriculture.

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wet ground usually occurring near an underlying shale ridge, point, or knoll which discharges water into the soil immediately surrounding it.

The possibility of reclaiming the water-logged and alkaline shale lands has been demonstrated in numerous instances; the purpose of this bulletin is to explain how and why the shale enters into the problem and to present the principles and methods upon which the reclamation of this type of land depends.

GEOLOGICAL FEATURES.

In the drainage of shale lands some knowledge of the underground formations is essential, as the seepage water often is under pressure and the problem is similar in some respects to one of developing an artesian supply. The water may move for considerable distances at depths that can not be reached by drains and may appear on the surface at some lower point. Ordinary methods of drainage fail because of the pressure and the resulting upward movement of the water. A proper solution of the problem requires a careful study of the source and direction of ground-water movement. Obviously, this necessitates a knowledge of the strata carrying the water.

The area to which this bulletin pertains is situated in the Rocky Mountains and on the high plateau areas immediately adjacent. The land usually is at a high elevation, the slopes steep, and the topography very rough. The rivers usually are hemmed in by high rock bluffs where they emerge from the mountains into valleys that are more open and gentle in slope. These valleys often are characterized by a sharp ascent to a gravelly mesa on one side and by a long gradual slope on the other side. Some distance back from the stream the ascent is broken by terraces of gravel or sand, or by tracts of clayey "bad lands," and here and there by rocky cliffs and mesas.

Shale is a finely stratified or laminated rock, formed from the stratification of clay, silt, or mud. In some of the so-called paper shales (Plate III, fig. 2) there are as many as 30 or 40 laminæ to the inch, each representing a separate stage of stratification.

Numerous varieties of shale structures are encountered which influence the movement of the underground water; however, this discussion is limited to the following three distinct types that have a wide range: Type No. 1, hard, calcareous shales that have suffered little or no displacement; type No. 2, shales, the layers of which dip very steeply; and type No. 3, shales in which the layers are horizontal or nearly so, but which have been subjected to great pressure.

Shales of the first type need little description. Being hard, poorly laminated, and lacking fissility, they more nearly represent the popular conception of shales which classes them among the less pervious geological strata. They probably are not capable of containing more than 4 per cent of water.[1] Their value as a water-carrying medium may be considered negligible.

The second type is to be found along the sharp-crested and well-defined "hogbacks." These usually are steep ridges which affect all of the formations immediately adjacent to them, the general uplift having tilted the layers of shale until they dip sharply and, in fact, in some places are nearly vertical (see Plate I). The pitch of these layers, however, decreases with depth and the distance from the hogback. In the uplifting process they have slipped, broken and shattered in a very complex manner.

The third type usually is found in folds of great extent, where the displacement has not been so intense and the layers or strata do not vary far from the horizontal. The layers, however, are by no means continuous and unbroken. If in the elevation of land areas the only forces are those acting in vertical lines so that the strata remain horizontal, cleavage may not be introduced, but if there are great forces acting horizontally, cleavage may be developed. "Whole mountains of strata may be cleft from top to bottom in thin slabs along planes parallel to each other."[2] This is well illustrated along the sides of a deep cut in an irrigation ditch shown in Plate II, figure 1, which cuts across a number of these cleavage planes. Plate II, figure 2, also is a good example of this. "The planes of cleavage seem to have no relation to the strata, but cut through them, maintaining their parallelism, however the strata may vary in dip. Usually the cleavage planes are highly inclined and often nearly perpendicular.[2]

Owing to the fissile nature of the shale, the compression also has caused shearing planes along the bedding planes. These, in turn, have become broken and in excavation the shale comes out in large flakelike pieces (Plate III, fig. 1). In some instances where the pressure has been intense, fault planes have developed. Plate III, figure 2, illustrates one of these, showing the shale layers to have slipped about 18 inches. The extremely broken and shattered conditions along this fault plane show clearly that it would carry water quite freely.

SURFACE TOPOGRAPHY.

During remote times the shale formations were subject to erosion and formed a topography of their own, similar to that of the exposed shale which can be seen at the present time. Erosion has produced "bad land" topography differing in character according to the local conditions. On the higher slopes, where erosion was especially vigorous, the shale is cut by deep, V-shaped ravines, the sides of which are very steep or nearly vertical (Pl. IV). Sometimes knolls or domes occur, as illustrated by Plate V. The bottoms of the

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[1] U. S. Geol. Survey, Water Supply and Irrigation Paper No. 160, p. 72.
[2] Elements of Geology, Le Conte, p. 189.

ravines usually are hard and solid, for the small streams have carried away the loose shale; but the ridges are covered to some depth with loose, broken, flakelike shale which has been formed by weathering.

With the exception of some of the higher ridges and knolls, the shale in the river valleys has been overlain with a covering of soil which varies greatly in depth. In general, the surface of these valleys has a configuration corresponding somewhat to the underlying shale surface, the minor irregularities of which are masked by the overlying soil. In the design of a drainage system the locations of these minor and abrupt irregularities must be determined by a large number of subsoil borings. This is made difficult by the flakelike covering over the solid shale, for this flakelike shale is found in other places at various depths in the soil, where it has been washed, and is not underlain by the solid formation.

UNDERGROUND WATER.

The collective medium for the underground water is the soil, especially those higher and more porous portions where irrigation is heavy, and also those higher exposed portions of broken shale in which canals and reservoirs have been constructed.

PRESSURE CONDITIONS.

The underground water usually exists under pressure. This fact, together with the moisture retentiveness of the soil, renders drainage difficult. After having stated that the mantle of soil in the higher land acts as a collective medium, it may seem inconsistent to say that it serves as the confining agency in the artesian conditions that exist at lower levels. However, the existence of artesian conditions does not necessarily require that the confining strata be wholly impervious, but only that they be less pervious than the water-bearing stratum. The top formation may be penetrated by considerable quantities of water, so that the leakage is large, and yet be available as a confining agent. This loss merely causes a reduction in pressure and volume. If it were not for the leakage, the head which the water derives from the highest zone of intake would continue under the entire region, but owing to this leakage there is a gradual diminution as the distance from the source increases.

The fact that the soil is less porous and offers greater resistance to the movement of underground water than does the shale causes the soil to act as a confining agent, the efficiency of which increases with its thickness. There is little need that cover beds of highest impervious character be very thick, but when the degree of imperviousness is inferior the element of thickness, in itself, is not without consequence. This is true especially where low pressures exist. The thicker covering offers more frictional resistance as the degree of consolidation increases with depth.

The water pressure usually is low because of the frictional resistance of the shale, and because of the leakage through the cover bed which causes seepage areas where the shale ridges or points lie near the surface.

RELATION OF UNDERGROUND WATER TO SHALE.

Water moves through the pores and laminæ of shale so slowly that solid shale is of negligible value as a water-carrying medium. The displacements and uplifts, however, which caused these strata or layers to be traversed by faults, cleavage planes and joints, or which caused them to assume sharp dips, have left this shale in a comparatively permeable condition.

Those hard, calcareous shales mentioned earlier (type 1, p. 2), which have not been disturbed and which are poorly laminated, do not carry water to any great extent and for all purposes of this discussion may be considered as impervious strata, the principal movement of the underground water being laterally over the shale surface.

In the second type of shale, as mentioned on page 3, the water is carried principally between the nearly vertical shale layers, as illustrated by Plate I, and the principal direction of its movement is of course parallel with the strike, especially in the deeper and less fractured zones. These water carriers have no regularity in spacing, which may vary from a small fraction of an inch to several inches. They are partly surface phenomena and diminish in number rapidly with depth and probably are better developed in the hills than in the valleys. Since the pitch of the strata usually decreases with depth, the surface of a valley cuts across a less number than does the surface of a hill.

In the third type of shale referred to on page 3 the important water carriers are the nearly vertical planes of cleavage (Pl. II) which cut at close intervals across the more or less horizontal strata. The distance between these planes may be only a few inches, but usually the larger and more important ones are a much greater distance apart. They vary in length from a few feet to hundreds of feet. While they influence the general trend of the direction of movement of the underground water, they may not be the immediate cause of seepage areas, for these planes are connected with each other and with the sloping surface of the shale by zones and widespread areas of shale that has been shattered and broken by shearing along its bedding planes.

All shales that have been subjected to intense pressure and displacements are traversed by numerous fissures or joint cracks, and these openings carry a large portion of the water. The prominent joints may extend several hundred feet, but even though the continuity of the individual joints be short, the minor intersecting fissures may cause long continuous openings. A knowledge of this condition is very important in determining the nature of the circulation of the underground water. Naturally the circulation is greatest where the vertical joints and horizontal fractures are most open and numerous.

MOVEMENT OF WATER.

The joints and cleavage planes serve as the principal channels for the free circulation of the water, and it is apparent that a well must strike one or more open fissures in order to obtain water. The evidence for this statement consists (1) of observations on the correspondence of the direction of the major joints observable in the rock at the surface with the appearance of seepage in the lower areas; (2) of the fact that many wells have been drilled within a few feet of each other without encountering water at the same depth; (3) of the dissimilar pressures in adjacent wells of the same depth.

Often when water is struck in a relief well the rise is very sudden. Such a rise means that the water is under pressure and that enough of it is in the larger openings that extend back up the slope to cause the initial rise. Small sustained flows come probably from areas of close jointing which are more or less continuous. While the movement of water in the close joints is slow, yet the aggregate capacity for storage is many times that of the larger fissures. These areas of close jointing collect water during the irrigation season and gradually feed it out to such larger and freer channels as may cut across them.

While the greatest movement of the water is along the direction of the systems of joints, yet mechanical and other agencies have left the ridges and knolls of the shale so badly broken and shattered that often they carry water quite freely in other directions and may discharge water at their points regardless of whether they run parallel with or perpendicular to the system of jointing. This condition, together with the closing of joints and the rapid decrease in number and greater spacing with depth, makes it evident that there will be a much freer circulation of water in the upper portions of the shale, or rather, in the remainder of the upper portions which now form the ridges. This accounts partly for the phenomenon of water following the shale ridges and leaking from them rather than from the other portions.

This condition is illustrated on the contour maps in figures 4 (p. 28) and 7 (p. 33), where the surface of the ground, the ground water, and the shale have been represented by distinctive lines. The most interesting feature of the maps is the general resemblance of the water contours to those of the shale, showing the influence of the shale topography on the movement of the underground water. In figure 4 a rather broad shale ridge is shown to come in from the northwest corner, becoming more sharply defined toward the south. In the southwest quarter is a portion of a draw or embayment in the shale formation, the slope of which is quite steep. Here the surface of the water follows very closely that of the shale. In the northwest corner the water conforms in a general way with the shale surface, but this is a very wet seepage area and a point where the shale discharges considerable water into the soil above it. It is not to be expected that at such points the shale and water contours will agree closely. Farther down on the sharp-crested portion of the ridge there is a closer resemblance.

Profile A of figure 5 (p. 29) is taken along the shale with highest grade and shows a marked agreement in slope between the water and shale. Profile B of figure 5 is taken across the better defined shale ridge and illustrates very clearly the conformity between the surfaces of the shale and water. Figure 7 (p. 33) shows the point of a well-defined shale ridge. The similarity between the shale and water contours should be noted. Profile C of figure 8 (p. 34), taken across this well-defined shale ridge, represents very much the same condition as does profile B of figure 5. Profile D of figure 8 is taken along a shale ridge and its point, and shows the water closely following the ridge up to the sudden dip or change in grade and then passing out into the soil, causing seepage conditions.

ALKALI.

Aside from the problem presented in the drainage of shale lands, complete reclamation for agricultural purposes is further complicated by the fact that lands of this type are often strongly alkaline, so that where they have become water-logged and have been allowed to lie idle for several seasons they have developed a decided alkali problem in addition to the one of drainage.

As providing a criterion for determining the severity of the alkali problem of different tracts where drainage is a factor, it is believed that analyses of a limited number of samples of the soil water more nearly represent average conditions and consequently are of greater value than are analyses of the same number of samples of the soil. This view is held because the alkali in any tract of land always is more or less unequally distributed, and a wide range of results will be obtained from analyses of the soil, depending not only upon just what parts of the tract the samples are taken from, but also upon whether they represent the surface inch or surface foot or some other depth of soil. It is true, there will be also a variation in the quality of the soil-water from a tract, but in general the range is not so great as in the soil, and a few analyses will show whether it is high or low in salt content and will indicate the kinds of salts. Under ordinary conditions this is about all that is necessary to know in order to forecast the probable difficulty that will be encountered in bringing the land to a condition for cultivation subsequent to drainage.

Surface accumulations of the alkali salts should not be taken as conclusive evidence of a case of extreme alkali trouble, for when the soil water rises to such a height that the surface of the ground is kept moist by the capillary water, high evaporation results, and as only relatively pure water passes off in this manner, it follows that the salts are left at the surface. If this process continue for sufficient time, heavy incrustations of salt may form on the ground surface irrespective of whether the soil water is highly or slightly alkaline, though the higher the percentage of alkali in the soil water the more rapid the accumulation of the salts by evaporation. Consequently, the more alkaline the soil water the greater the necessity for immediate relief by drainage. The necessity of the drainage of those shale lands that have become water-logged is shown from a study of the following tables. Table I contains the results of analyses of soil water as discharged from 10 newly installed drainage systems on tracts at one time under cultivation. Samples A and B in Table II are two samples of seepage water through shale from a canal the first season after construction. Sample C in Table II is seepage water in a valley in the bad-land topography shown in Plate IV.

TABLE I.—*Analyses of drainage waters from systems in shales.*

(Tracts at some time under cultivation.)

Substance.	Milligrams per liter (parts per 1,000,000).									
	1915, Feb. 1.	1914, May 26.	1914, Apr. 27.	1914, Apr. 27.	1914, June 11.	1914, May 8.	1915, Mar. 30.	1915, Mar. 14.	1916, Feb. 15.	1916, Feb. 15.
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.
Ions.										
Sulphuric acid (SO_4)	2,542	8,566	24,932	25,382	3,132	13,320	10,508	5,500	6,372	20,470
Carbonic acid (CO_3)	......	......	12	15.2	......	......	......	......	......	50
Bicarbonic acid (HCO_3)	467	556	583	728	348	632	513	427	861	688
Nitric acid (NO_3)	14.2	398	1,253	982	200	832	286	443	4,861	7,614
Chlorine (Cl)	41	172	294	305	156	490	262	378	232	428
Calcium (Ca)	517	428.5	427	452	505.5	425	405	453	602	492
Magnesium (Mg)	381	1,016	2,754	3,333	362.5	878	600	570	1,315	2,746
Sodium (Na)	111	2,156.7	7,123	6,178	540	5,094	3,901	1,606	2,151	7,442
Total	4,073.2	13,293.2	37,378	37,375.2	5,244	21,671	16,475	9,377	16,394	39,930
Hypothetical combinations.										
Sodium carbonate (Na_2CO_3)	......	......	......	......	......	......	......	......	......	88
Magnesium sulphate ($MgSO_4$)	1,886	5,030	13,633	16,499	1,795	4,346	2,970	2,822	6,510	13,593
Sodium nitrate ($NaNO_3$)	19.2	545.6	1,718	1,346	274	1,140	392	607	6,664	10,438
Sodium chlorid (NaCl)	68	283.5	485	503	257	809	432	623	382	706
Sodium sulphate (Na_2SO_4)	244	5,860.5	19,975	17,346	1,127	13,798	11,196	3,695	609	13,287
Calcium sulphate ($CaSO_4$)	1,236	835.5	773	689	1,329	739	803	1,063	1,085	904
Calcium bicarbonate ($Ca(HCO_3)_2$)	620	738.1	774	967	462	839	682	567	1,144	914
Calcium carbonate ($CaCO_3$)	......	......	20	25.2	......	......	......	......	......	......
Total	4,073.2	13,293.2	37,378	37,375.2	5,244	21,671	16,475	9,377	16,394	39,930

TABLE II.—*Analyses of seepage waters through virgin shales.*

(No land lying above ever under cultivation.)

Substance.	Milligrams per liter (parts per 1,000,000).		
	1915, Nov. 18. A.	1915, Nov. 12. B.	1916, Apr. 29. C.
Ions.			
Sulphuric acid (SO_4)	4,236	21,800	37,612
Carbonic acid (CO_3)	.....	96	77
Bicarbonic acid (HCO_3)	434	849	710
Nitric acid (NO_3)	4,004	577	1,687
Chlorine (Cl)	480	1,038	2,783
Calcium (Ca)	1,110	567	535
Magnesium (Mg)	523	2,481	2,556
Sodium (Na)	1,725	6,376	15,318
Total	12,512	33,784	61,278
Hypothetical combinations.			
Sodium carbonate (Na_2CO_3)	.....	170	136
Magnesium chloride (MgCl)	148	.....	.....
Magnesium sulphate ($MgSO_4$)	2,402	12,282	12,653
Sodium nitrate ($NaNO_3$)	5,489	791	2,313
Sodium chloride (NaCl)	609	1,711	4,588
Sodium sulphate (Na_2SO_4)	.....	16,723	39,620
Calcium sulphate ($CaSO_4$)	3,287	979	1,025
Calcium bicarbonate ($Ca(HCO_3)_2$)	577	1,128	943
Calcium carbonate ($CaCO_3$)	.....	.....	.....
Total	12,512	33,784	61,278

These are all bad waters, as only three of the 13 samples show less than 10,000 parts per million, or 1 per cent, of the soluble salts, and one of these is but slightly below this figure. The average for the 13 samples is slightly in excess of 23,700 parts per million, or 2.37 per cent.

An acre-foot of water weighs 2,722,500 pounds and with a salt content of 23,700 parts per million will contain 64,523 pounds of salt. Assuming the weight of an acre-foot of soil at 4,000,000 pounds, the salt that would be left in the soil by evaporation from it of but a single acre-foot of this water would be equivalent by weight to 1.6 per cent for the top foot of the soil. If this quantity were distributed throughout a depth of 4 feet, it would mean an average of four-tenths of 1 per cent. It is conservative to assume an annual evaporation of 36 inches under such climatic conditions as exist in those sections of the United States to which this bulletin refers, so that it would require but one season to deposit enough salts, by evaporating the average of the waters represented by Tables I and II, to make the situation three times as bad as the above. Allow surface evaporation, resulting from poor drainage, to continue for a number of years and the situation with respect to alkali is rendered extremely serious.

Many investigators, working independently, have attempted to establish a comparative standard relative to the tolerance of plants for the different alkali salts present in a soil. Owing to the variety of combinations and soil and moisture conditions under which these injurious salts may occur, it is not possible to state definitely the highest percentage a soil can contain and still support ordinary vegetation. However, in order to convey a general idea of what is meant by an alkali problem, the results of recent and very extended experiments by Frank S. Harris, professor of agronomy, Utah Experiment Station, are summarized in part as follows:

[1] In this paper results of over 18,000 determinations of the effect of alkali salts on plant growth are reported. * * * Only about half as much alkali is required to prohibit the growth of crops in sand as in loam. * * * The toxicity of soluble salts in the soil was found to be in the following order: Sodium chlorid, calcium chlorid, potassium chlorid, sodium nitrate, magnesium chlorid, potassium nitrate, magnesium nitrate, sodium carbonate, potassium carbonate, sodium sulphate, potassium sulphate, and magnesium sulphate. Land containing more than about the following percentages of soluble salt are probably not suited without reclamation to produce ordinary crops. In loam, chlorids, 0.3 per cent; nitrates, 0.4 per cent; carbonates, 0.5 per cent; sulphates, above 1 per cent. In coarse sand, chlorids, 0.2 per cent; nitrates, 0.3 per cent; carbonates, 0.3 per cent; and sulphates, 0.6 per cent.

Using the figures as given by Prof. Harris as a basis for comparison, it is apparent that great danger to crops from alkali exists in those lands represented by the foregoing samples of drainage water, provided the water be allowed to rise above the root zone of any cultivated plant. If the rise be such as will permit of evaporation from the ground surface, it also is obvious that the trouble will be aggravated rapidly.

Illustrating this latter point, there follow the results of the soil analysis of a composite of two samples at each depth taken from near the center of about 4 acres that produced thrifty alfalfa previous to the season of 1913, but which became so wet the summer of 1913 that water rose to the surface of the ground and ran off through the waste ditches. Needless to say the land became wholly unproductive.

TABLE III.—*Salt content of shale-land soil.*

Substance.	Parts per 100,000 of soil by weight.						
	First foot.	Second foot.	Third foot.	Fourth foot.	Fifth foot.	Sixth foot.	Average.
Sodium chloride ($NaCl$)	178	92	132	337	132	46	153
Sodium sulphate (Na_2SO_4)	44	231	141	1,166	53	620	376
Magnesium sulphate ($MgSO_4$)	278	535	377	615	615	436	476
Sodium bicarbonate ($NaHCO_3$)	116	116	149	116	132	116	124
Calcium sulphate ($CaSO_4$)	680	1,373	720	3,425	8,837	4,337	3,229
	1,296	2,347	1,519	5,659	9,769	5,555	4,358
Nitric acid (NO_3)	89	600	500	556	353	188	381

Attention is called to the fact that these soil samples, as well as the water samples in Tables I and II, are unusually high in the nitrates and carry also considerable sodium chloride. As noted

[1] Journal of Agricultural Research, U. S. Department of Agriculture, vol. 5, no. 1, Oct. 5. 1915.

earlier, Harris found that these two salts are extremely injurious to plant life, both ranking ahead of sodium carbonate in this respect.

The different alkalies, including the nitrates, present in large quantities in the shales and in the soils formed from the shales, had their origin in the brackish waters of the old inland seas.[1] That the nitrates present in the water samples of Table I are an inherent part of the virgin shales and not dependent upon conditions following cultivation is shown clearly by the analyses of the seepage waters in Table II, as all three of these samples came from tracts of desert lands that never were cultivated, nor was any land lying above them ever cultivated. The water represented by samples A and B in Table II was the direct result of losses from a new canal through which water had been run only for about six weeks during the latter part of the same season the samples were taken. Sample C represents seepage water just beneath Mount Garfield in the Bookcliff Range in western Colorado. The quantities of nitrates in these samples are remarkable, especially in samples A and C.

DRAINAGE METHODS.

Among the owners of shale lands many conflicting opinions are expressed as to the cause of seepage, and almost as many remedies suggested. Many drainage systems have been installed by landowners, with but little success. The ineffectiveness of ordinary drainage methods has been demonstrated repeatedly by the many failures in the arid West of methods which commonly are successfully practiced in the Middle West and in the East. Furthermore, even the methods that have been employed successfully in the drainage of the ordinary type of affected land in the arid West have failed when applied to shale lands. Shallow drainage is of absolutely no avail, and deep drainage with a small interval between drains fails also when the seepage water is supplied under pressure by outcropping or immediately underlying shale formations. Soil which is largely made up of shale belongs to the "adobe" type and does not respond readily, under ordinary conditions, to any type of drainage; and where shale furnishes the water under pressure, drainage systems must be designed which will take the water from the shale before it reaches the soil.

EFFECTIVE DRAINAGE.

PRELIMINARY EXAMINATIONS.

Effective drainage of shale lands depends upon the location and depth of the drains and upon the proper installation of relief wells. To locate the drains properly is a slow and laborious process, for it

[1] Stewart, Robert, and Peterson, William. The Nitric Nitrogen Content in the Country Rock. Utah Experiment Station, Bulletin 134, 1914.

requires the mapping—or at least the gaining of a correct idea of the surface topography—of the underlying shale. This necessitates a large number of borings and very careful subsoil examinations, owing to the sudden changes and extreme irregularity in the shale topography. On some tracts the surface of the underlying shale is fairly regular and not a great many subsurface examinations are required, but in many instances the shale has been eroded into bad-land topography (Pls. IV, V, and VI, fig. 1). The auger at one point may strike the top of a shale knoll, dome, or point immediately underlying the covering of soil, while 20 feet away in any direction it will not encounter shale at a depth of 10 to 20 feet. (See profiles C and D, fig. 8, p. 34). Very narrow ridges often are found, the tops of which are near the ground surface, but a short distance on either side the shale is too deep to be reached by tile drains. A common occurrence in the shale formation is a very deep and quite wide arroyo running through a rather smooth area of shale, but with no indication of this deep depression, owing to the covering of soil.

Where only small areas are affected the shale knoll, or point, contributing the seepage water may be located sometimes by ascertaining from the landowner the spot where seepage first made its appearance. The damaging features of the underlying shale topography often can be quickly ascertained by a line of borings closely spaced along the upper edge of the affected area. Where large areas are affected, and where an idea must be gained of the topography of the shale underlying the entire district, perhaps the most rapid method is to begin with a boring at each of the extreme corners of the tract, then to subdivide the distances between these holes, continuing the process until a sufficient number of borings have been made to determine the general features, after which those spots or localities which seem to overlie points or ridges can be more carefully examined. In cases where the conditions are very complex, and it is desired to map the underlying shale, it is best to space the majority of the holes regularly over the area in question.

The topography of the underlying shale usually resembles the present surface topography in a very general way. In the bottom or older portions of a valley that are more or less even and uniform, the underlying shale usually is also fairly smooth. On the slopes the more pronounced ridges are often underlain by shale ridges which represent the general trend of the system of shale topography. Frequently outcroppings of shale will give an idea of the underlying features. In some cases large underlying shale draws can be located by noting the gaps and openings in hills forming the rim of the valley. A knowledge of the kind of shale being dealt with and its characteristic topographic features is of value in gaining a general idea of its surface.

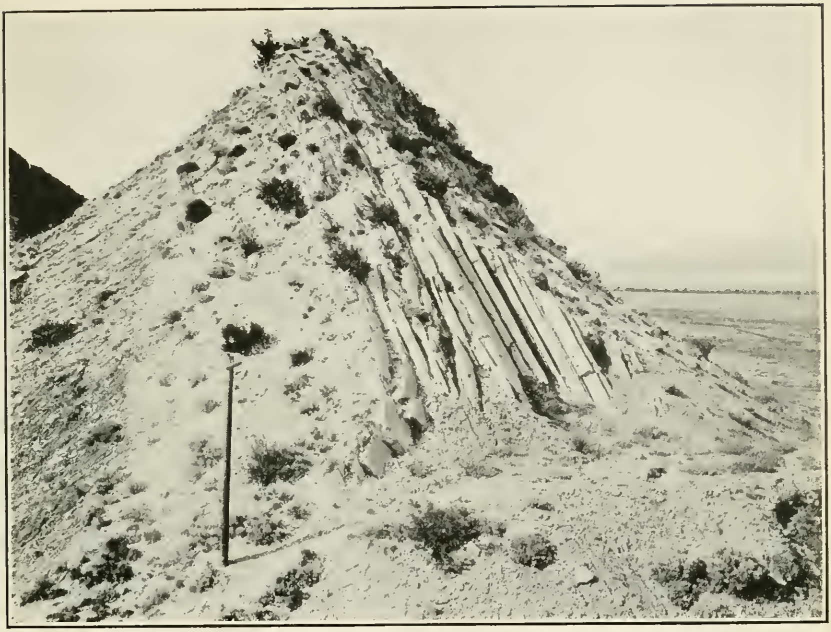

FIG. 1.

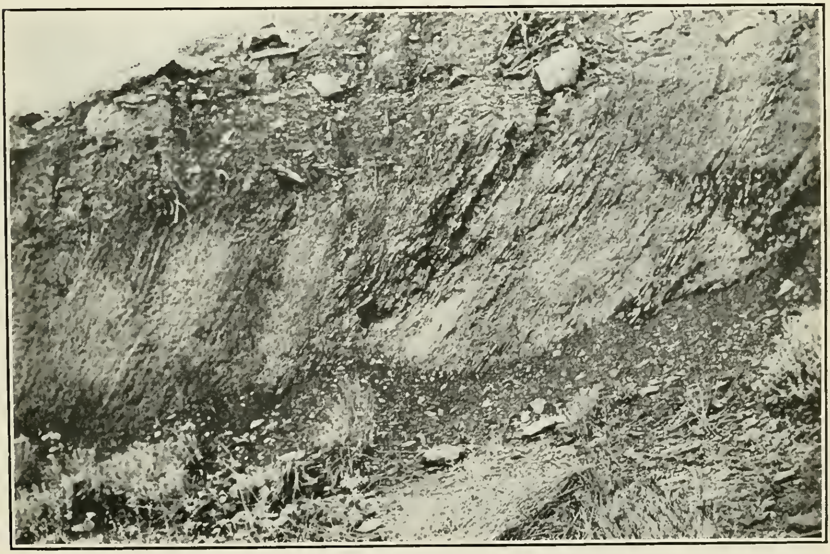

FIG. 2.

SHALE WHICH HAS BEEN UPLIFTED UNTIL THE LAYERS DIP SHARPLY.

FIG. 1.—SIDE OF AN IRRIGATION DITCH, SHOWING NEARLY VERTICAL CLEAVAGE PLANES.

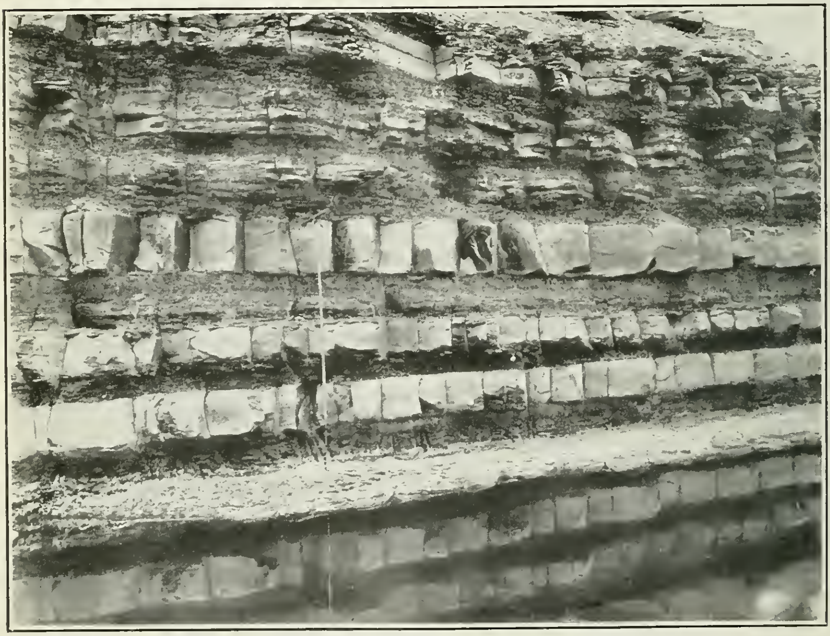

FIG. 2.—SHALES HAVING NEARLY HORIZONTAL LAYERS WHICH HAVE BEEN CUT BY CLEAVAGE PLANES CAUSED BY GREAT PRESSURE.

Cleavage planes continuous through shale layers and intervening rock strata.

FIG. 1.—PRESSURE HAS CAUSED SHEARING ALONG BEDDING PLANES; WHEN EXCAVATED THE SHALE COMES OUT IN LARGE FLAKELIKE PIECES.

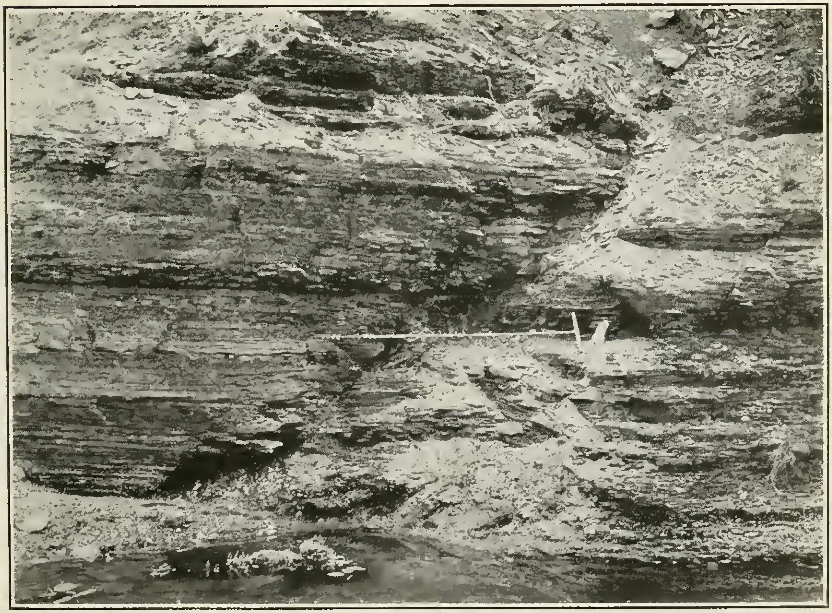

FIG. 2.—WHERE PRESSURE HAS BEEN EXTREME, FAULT PLANES HAVE DEVELOPED.

EFFECTS OF INTENSE PRESSURE ON SHALE.

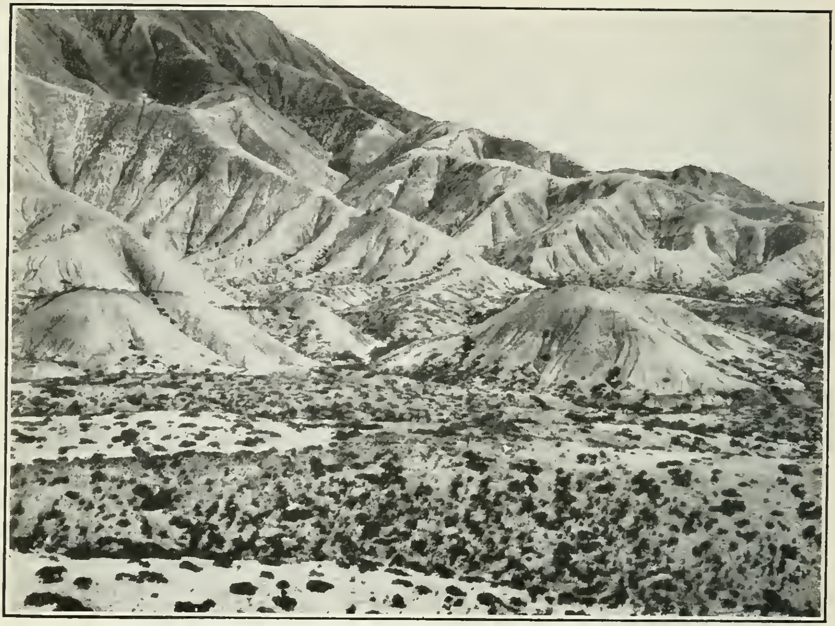

FIG. 1.

FIG. 2.

"BAD-LAND" TOPOGRAPHY, PRODUCED BY VIGOROUS EROSION OF THE HIGHER SLOPES.

FIG. 1.

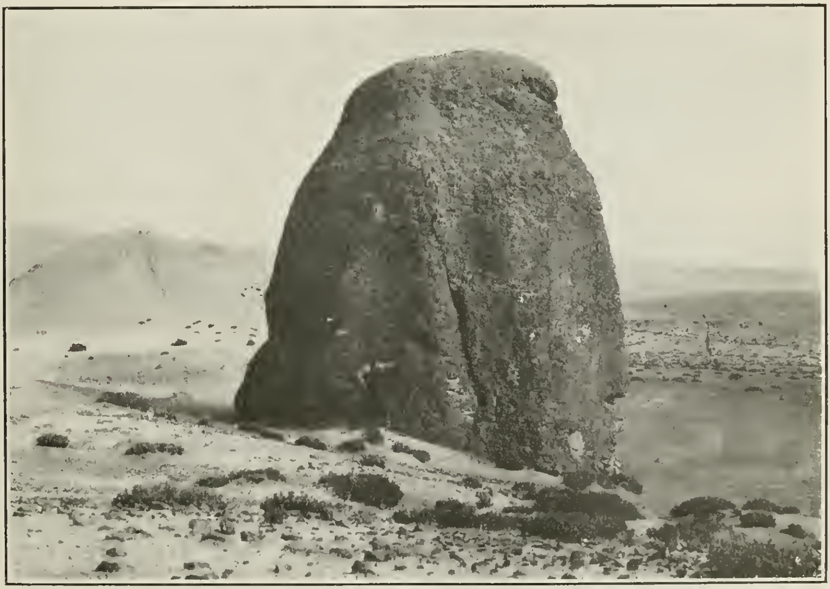

FIG. 2.

"BAD-LAND" TOPOGRAPHY. A SHALE KNOLL (FIG. 1) AND A SHALE DOME (FIG. 2).

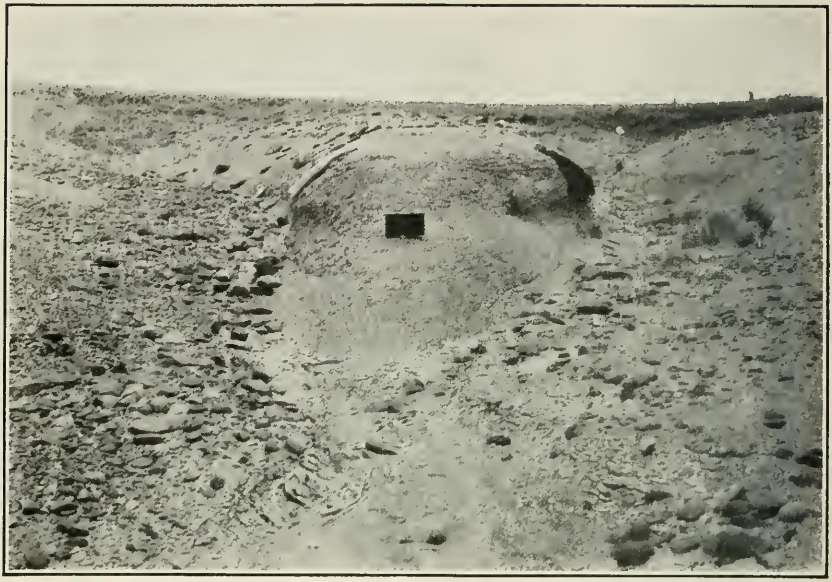

FIG. 1.—"BAD-LAND" TOPOGRAPHY. A SHALE POINT.

FIG. 2.—WET AND ALKALIED LAND.

At one time this tract produced alfalfa. (See Example VI, p. 32.)

In making the examinations a small stake should be driven at each hole and the stakes numbered consecutively. If a map is to be made, the depth to shale should be kept in a notebook. Otherwise the depth to shale should be marked on each stake in order to facilitate locating the drains along the ridges and other higher portions of shale.

The weathered, flakelike covering of the shale ridges, mixed with soil, frequently makes it difficult to determine the true depth to the solid shale formation, as pockets of coarse shalelike material occur in the soil and may be far from any shale formation; consequently examinations of borings from small auger holes frequently are misleading. Where there is any doubt, holes should be continued for some depth after encountering the shale to make sure that it is the solid formation. Occasionally, where the exact depth to shale seems uncertain, it can be ascertained best by excavating a pit.

LOCATION OF DRAINS.

Attempts to accomplish drainage by running tile lines across and along the upper edge of the affected area (see lateral A, fig. 9, p. 35), thereby cutting into a number of shale ridges and points contributing water, have proved unsatisfactory; (1) because of the absence of an impervious stratum that can be reached by the tile, the lack of which permits some of the water to pass freely below the tile to a point farther down the slope; (2) these ridges do not discharge water at their points alone, but frequently along the sides also. This is due to the fact that pressure exists and the water is supplied at various points from the continuous shale formation beneath the shale ridge.

These complex conditions existing in the shale make it imperative that the drainage lines should follow as nearly as possible along the backbone of the shale ridges or cut through the knolls and other high portions. Usually the lines should extend for some distance up the ridge or other formation above the affected area. Not only is it necessary to run the tile lines along the shale ridges to secure the best results, but trenching in the shale is far easier than in wet adobe soils. Where quite broad shale ridges are encountered, one line will be insufficient; on such ridges a tile line should extend along each side (lateral C, fig. 9, p. 35).

Where a number of shale ridges that are supplying the seepage water are encountered the main line should, if possible, run along the points of these ridges, with a branch following up each ridge (lateral B, fig. 9, p. 35). As not all shale ridges, or points, furnish seepage water, a number of deep holes should be put down into the shale, noting the degree of hardness, whether or not soft layers are encountered, the amount of water found, and whether or not pressure conditions exist. It is very important that none of these shale points that contribute water be missed, for, although the system may develop a considerable quantity of water from the points tapped, any remaining one will furnish enough water to these retentive adobe soils to prevent complete reclamation.

In the drainage of those lands underlain by shale that has no distinctive topographic features, but which is smooth and at a fairly uniform depth below the surface of the soil, a system should be employed which has branches spaced at regular intervals and extending up the slope. However, the determination of the interval required for the branch lines necessitates a careful examination of the shale. Experience in drilling often will enable one to determine whether or not the shale is traversed by systems of small crevices; the drill takes hold with more difficulty in shale that does not contain them than in shale that does. The nature of the borings brought out on the auger is indicative also of the presence or absence of such crevices. If the borings are fine-grained and more or less compact, few or no crevices are probable: but flaky, mealy borings indicate the contrary. By those unfamiliar with the mode of occurrence of water in shale those zones containing water often will be overlooked, for the small lumps and layers of shale between the cracks are impervious in themselves, and the auger, passing through these, will bring up fragments of perfectly dry shale, while the free water frequently found between these dry borings will be thought to have collected there in pulling the auger out through the upper wet portions of soil.

The existence of pressure often can be detected after having struck cracks in the shale containing water, by placing the ear near the hole; a hissing sound caused by the escape of the water from the small crevice into the larger opening is an almost certain indication of pressure conditions. The intensity of the pressure can be estimated by the rapidity and height of rise of the water in the well. Often the water will rise several feet within a few minutes, and again it may require a day or two for it to attain its maximum height. Where the water rises only a few inches, and that very slowly, the pressure is slight or negligible. High pressure is indicated by a rapid and high rise of the water. Of course, the height and rapidity of rise depend somewhat on the season, there being generally a seasonal fluctuation of the water table. In seasons of high water table, pressure strong enough to cause these wells to flow on the surface is encountered frequently.

The borings will indicate certain spots and streaks where the pressure seems high and the water free; drainage lines should be located to tap these areas. Figure 1 is an example of the application of the information obtained from the borings. It becomes apparent at once where the two most important lines should be located—one 120 feet from and parallel with the east fence line, and the other 45 feet from and parallel with the south fence line.

In the location of drains in those lands underlain by hard and practically impervious shale interception methods can be used, provided the shale surface is even and sufficiently near the ground surface to be reached by a tile drain throughout the entire length of the line; otherwise this method can not be used, and the overlying

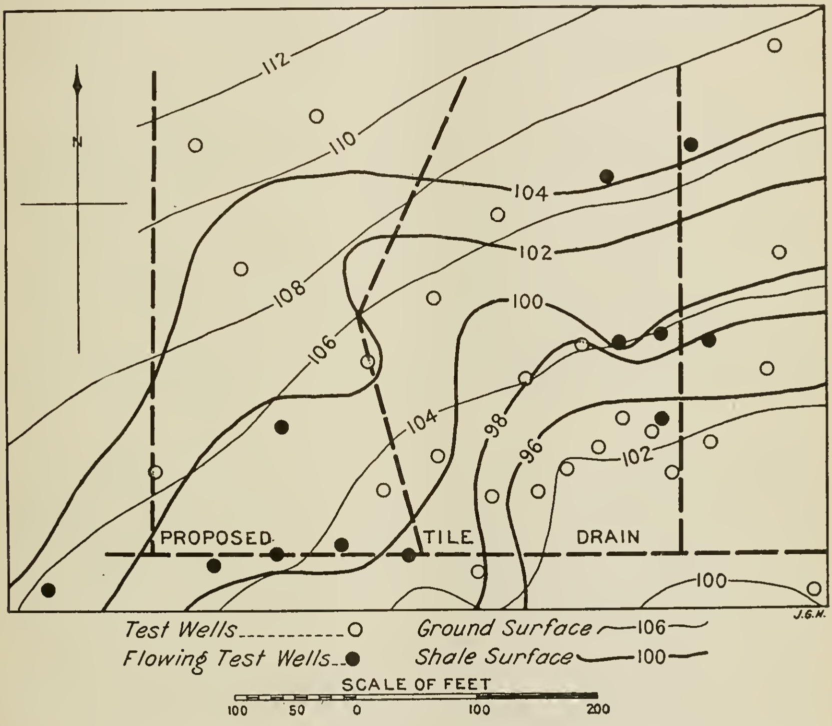

FIG. 1.—Map of an eight-acre tract, showing borings made and data obtained therefrom.

soil must be drained by a relief system. However, even where the interception system can be used, it often is the case that in large tracts supplementary drains will be needed to remove the water from the already saturated soil and to provide outlet for the large quantities of water that must be applied to wash out the heavy accumulations of alkali.

DEPTH OF DRAINS.

The tendency in the arid West has been toward increasing the depth of drainage; this has been true especially with regard to shale lands. The distance through which capillarity takes place is one of the important factors regulating the minimum. Water passing upward through the soil by capillary action carries salts in solution and by evaporation deposits them on the surface of the ground. The height to which capillary water will rise depends on the type of soil, its wetness and temperature, and, to some extent, on the kind of salts. High temperatures and certain salts increase the range of capillarity. In loose, sandy soils the rise is not great; in average soils of the arid West it probably ranges from 2 to 4 feet, and in clayey soils more than this. Of all the types of soils, the adobes encountered in the drainage of shale lands are perhaps most conducive to a high range of capillarity; thus the necessity for deep drainage.

One of the greatest advantages of deep drainage in this type of land is the increase of flow of the relief wells thus obtained. However, there is a practical limit to the maximum depth, and it is believed that in the design of a drainage system the depth should be fixed with reference to that limit rather than by setting a minimum limit determined by capillarity, depth of root zone, etc. The practical limit of depth, of course, would vary somewhat as between hand work and machine work. It would depend also upon the nature of the ground encountered. In the presence of these variable factors it becomes impossible to fix a maximum depth, but the minimum should be not less than 6 feet and in many cases should be 7 or 8 feet.

PURPOSE OF RELIEF WELLS.

In the drainage of many types of shale land the installation of relief wells is absolutely necessary for the success of the drainage system. A relief well is nothing more nor less than an artesian well. This does not mean necessarily that the water rises to the surface and overflows, since any well may be considered as artesian where the water rises to some extent after having been drilled through a comparatively impervious stratum into one carrying water; in other words, where the water enters the well under pressure.

As mentioned before, the seepage areas in shale lands occur almost invariably where pressure conditions exist and the movement of the water is upward. In cases of extreme pressure this can be detected at the surface by the appearance of drops of water that have been forced up through the small pores of the soil. In but few cases, however, is it possible to place the drains deep enough to reach the supply of water that causes the saturation. Often the water-carrying zones of shale have been found at depths approximating 30 feet. The cost of the installation of drainage lines becomes prohibitive long before this depth is attained, but unless the water-carrying medium is reached in some manner drains will be of little service, no matter how carefully they are located and constructed or how closely spaced. Cases are known where drainage systems had been constructed in shale to a depth of 7 feet and had developed considerable quantities of water, yet seepage water rose to the top of the soil within a few feet of the line and ran off the edge of the bank into the trench. Flowing springs have been found within 10 feet of a 7-foot trench. Such results indicate clearly that ordinary methods of drainage will not relieve seepage conditions where the water is supplied under pressure.

The purpose, then, of the relief well is to connect the tile line with the deeper strata which are the sources of the seepage water and thus, by permitting the water to pass out freely, to relieve the pressure.

ACTION OF RELIEF WELLS.

The pressure of water in a well depends upon the height of the source, the quantity of water supplied, and the extent of leakage and amount of friction encountered between the source and the well. In speaking of this pressure the term "static head" is used to designate the pressure at the point where the flow is measured, when the well is closed. The static head is expressed in terms of the height above the point of measurement to which the water will rise in the well. The discharge of a well is directly proportional to the static head. The flow of a relief well is measured at the point where it discharges into the tile line. If the point of measurement were at the surface of the ground, many relief wells would have no static head and consequently would not flow. A well in which the water rose to within 1 foot of the surface would have a static head of 6 feet if measured at its connection with a tile line 7 feet deep. Thus the advantage of deep drainage can be seen readily, as increasing the depth increases the flow from the relief wells. A well that has a static head of 3 feet in a ditch 4 feet deep would discharge twice as much in a ditch 7 feet deep. A better appreciation of this advantage of depth will be gained when it is realized that in this class of drainage work the wells supply the major portion of the drainage water.

As explained in the description of the shale formations, the water-carrying zones are not continuous or regular, and several different crevices and zones of close jointing probably furnish the flow to one small seepage area. These water-carrying zones may not be freely connected—at least in the immediate vicinity of the seepage area—and each one may have a pressure slightly different from those of the others. The area affected by each of these small contributing features probably is quite small. The pressure of the water, although it may have a high source, usually is very low, owing to friction encountered in the small fissures of the shale. When these crevices or closely jointed zones disappear or pinch out, the water has a tendency to move upward because of the more or less vertical nature of the crevices. Often where the overlying soil is thick, dense, and compact, the resistance offered overcomes the low pressure, and the water penetrates up into it but a little distance; but where the depth of soil is not great the water penetrates up through it and runs off the surface. More frequently, however, the friction of the soil overcomes the low pressure of the water before it quite reaches the surface, and a stationary condition would result but for a slight lateral movement of the water in the soil which causes it to spread over a more or less circular area larger than the outlet of the contributing feature in the shale.

The condition just described is relieved by wells reaching into and tapping the water-bearing zone; for the water, seeking the path of least resistance, enters the larger openings formed by the wells and passes freely upward and outward. One well, or a number of wells, will not remove all of the water from the water-bearing stratum or area, but they tend to relieve the pressure and thus prevent the further rise of water to the small area of soil above. The relief of pressure by this method is based on a well-known principle of hydraulics, viz, that the pressure of flowing water in a confined medium decreases with the increase of velocity.

It is well known that in any artesian area wells too closely spaced will interfere; that is, the discharge from each well will be reduced as the number of wells in the area is increased. In the drainage of shale lands the relief wells should be spaced so closely that this interference practically overcomes the pressure between the confining strata. Otherwise, since these confining strata always are more or less imperfect, water will continue to rise into the subsoil and the land will remain water-logged, even where immediately adjacent to drains, whether open or covered.

The relation between the tile drains and the relief wells in a drainage system can be summed up in the statement that the relief wells provide the desired drainage, while the tile drains merely provide outlets for the water developed by the wells.

AREA OF INFLUENCE OF RELIEF WELLS.

The area of influence of an ordinary relief well in shale is not large. A well may strike but one small crevice or water-carrying zone which is responsible for only a very small spot in the seepage area and which is only one among many that are contributing water. While no rigid rule can be given for the spacing and location of wells, experience has shown that from two to six for each 100-foot length of trench will be necessary ordinarily. This does not mean, however, that a certain number of wells should be decided upon for a unit length of trench and then spaced evenly throughout that length. While the location of a well that will develop the maximum flow, or any flow at all, is a very uncertain matter, the amount of water developed in the bottom of the trench as it progresses is a very good indicator. Those points that develop the most water show that they are probably underlain by water-bearing zones and that the pressures are higher there than elsewhere. Evidently a well located at such a point will develop a larger flow and will be more beneficial than one placed elsewhere. Where the greater amounts of water are found in the trench and the higher pressures seem to prevail, wells should be located quite close together. They should be spaced further apart in the drier portions of the trench. Where the conditions in the trench are uniform, the wells should be spaced regularly if the resulting flows are uniform; but if, after putting down a hole or two, very little or no flow results, it is advisable to space them farther apart until an area is encountered where more water is developed.

DEPTH OF WELLS.

The proper depth for relief wells is a matter for experiment in different localities. The maximum depth, however, usually is about 20 feet below the bottom of the drains. It becomes difficult to drill wells deeper than this by hand, and as a rule their effectiveness is not increased by the additional depth. In any event, water encountered at this depth probably is not contributing to the seepage area in the immediate vicinity. In beginning work on a new project it always is advisable to drill the first two or three wells deep to determine where the flow is most apt to be encountered. While water will not be encountered at uniform depths, yet certain limits within which it is likely to occur will be determined. In most of the work forming the basis for the conclusions in this bulletin the approximate depth at which the flows have occurred has been about 15 feet below the surface of the ground.

AMOUNT OF WATER DEVELOPED.

It will be found that some of the relief wells do not flow at all and that the discharge is small from many of those that do. In nearly all cases observed 2-inch wells have been of sufficient size to care for the water developed. Among other things, the amount of water developed depends upon whether it is the season of low or high water table. Many wells that do not flow when they are installed in the season of low water table discharge when the water rises again. Figure 11 (p. 37) illustrates the variation in discharge from a 1,600-foot system of drainage, where 1,000 feet of the tile were in shale and a total of 35 wells were installed, ranging from 12 to 20 feet in depth.

While there is no doubt that the relief wells furnish the larger part of the discharge from these systems, very few accurate data on this point are available. Information of this character has been difficult to collect because it is almost impossible to measure the discharge of the well except by noting the increase of flow at the outlet of the tile as the wells are installed. This could be done readily if the wells were installed after the line was completed, but construction in bad ground often necessitates the drilling of the wells as the work progresses, and this makes it impossible to determine how much water is developed by the tile line and how much by the wells. The following data were collected on a line of tile 350 feet long and 7 feet deep: When completed, the drain without relief wells discharged 3.2 gallons per minute. Six wells were installed in one day, immediately after which a measurement was made, which showed a discharge of 21.4 gallons per minute. Two of the six wells installed did not flow at all. Another line in this same system, and with the same length and depth, discharged 37.5 gallons per minute after completion. Twelve wells were installed in one day, after which the discharge was 85.7 gallons per minute. This latter example probably is more nearly representative of average results. About 300 feet of each of the above two lines were in shale.

CONSTRUCTION.

Construction of drainage systems in shale lands has varied greatly in respect to difficulty of installation and cost. Much of the shale is quite hard, or contains hard concretions, which makes necessary the use of picks. Trenches where the greater depths are in solid shale stand well and need little or no bracing if the work is handled properly. Shale makes a very good foundation for laying tile, and the coarse, broken shale is good material for blinding the tile.

Generally speaking, the work in shale is not difficult, but trenching in the saturated adobe soil is a real problem. Outlet lines usually have to pass for considerable distances through soil not immediately underlain by shale, and in many lines the upper several feet of the trench must be excavated through the soil before the shale is reached. With the exception of saturated fine sand or quicksand, no class of material is more difficult to handle than adobe. When partly saturated it becomes sticky and adheres to the materials and tools with a tenacity that makes progress difficult and tedious. The skeleton spade is the only tool that will handle it with any degree of success. The ordinary shovel will not scour. When this soil becomes completely saturated it often assumes a semifluid state that makes the use of tight sheeting necessary; frequently, not only must the sides of the trench be sheeted, but also the face.

The most successful cribbing in such material consists of two heavy timbers, held apart by trench jacks, behind which is driven the vertical lumber sheeting. The boards should fit tightly; they may be driven with a heavy maul and removed with a light derrick or grabhook. Where the sheeting is driven and pulled by hand, planed 2 by 6 inch planks have been found the most satisfactory. Sizes larger than this are driven and pulled with difficulty. The bottom end of each of these planks should have a long bevel on one side, so that it will drive readily and straight. The tops of the planks should be beveled slightly, or a cap used to prevent "brooming" while being driven, and the planks should be long enough to extend below the grade line. As the material is excavated, two more heavy planks should be placed near the bottom and held apart by trench jacks to prevent the weight of the material from displacing the bottom of the sheeting. These can be used also for the workmen to stand on when the bottom of the trench becomes too soft. In the latter event it becomes necessary to place boards under the tile in order to hold them on the grade and prevent them from sinking. When large-sized tile are used a cradle must be placed under them. This cradle resembles a ladder, the strips running lengthwise being of 2-inch material and spaced so that the sides of the tile will rest against them as well as on the crosspieces of broad 1-inch lumber. The tile should be covered by some material such as cinders, gravel, or broken shale. Hay and straw have been used with success. The tile should be well blinded and weighted down before removing the sheeting, which should be pulled slowly and carefully to prevent the soft material that sloughs in from the sides from pushing the tile off grade. Trenching machines especially built with shields for soft material would handle some of these soils satisfactorily.

The excavation of ditches should begin at their outlets or at their junctions with other drains and proceed toward the upper end. Trenching should be done as neatly as possible and should follow closely the line of stakes; where the drain changes direction the turn should be made by a neat curve. If possible, the top soil should be thrown out on one side of the ditch and the shale on the other, and in back-filling the shale should be put in first.

No attempt should be made to grade the tile by the water in the ditch. Grades for the drains always should be established by surveys, and the ditch should be dug accurately to the depths specified; these depths should be measured from the grade stakes set for that purpose, and the ditch graded evenly on the bottom by means of the "line and gage" method or by any other equally accurate device for obtaining an even and true bottom upon which to lay the tile.

The tile should be laid as close as possible, beginning at the lower end and proceeding upstream. They should be turned about until their upper edges close. If there is silt or other fine material that is likely to run into the tile, the lower edges must be laid close and the joint surrounded by cinders, gravel, or other suitable material. If, in making turns or by reason of an irregularly shaped tile, a crack one-fourth inch or more is left, it must be covered securely by broken tile. All junctions at manholes and branches should be made securely. Care must be exercised to prevent sediment from washing into the tile, and when each drain is complete it should be free from sand, mud, or other obstructions.

The tile should be hauled and distributed along the line of trench all in one operation. They should be hard-burned clay tile of good quality, preferably in 2-foot lengths. They should have smooth interior surfaces and should be hard burned entirely through, of uniform texture, and free from lime or other impurities. No piece should vary from a straight line more than one-half inch for a 2-foot length. No tile should be used that has a piece broken from either end deeper than 1½ inches. After the tile are laid they should be covered carefully to a depth of at least 6 inches with broken shale, gravel, or coarse cinders.

Relief wells can be installed with a 2-inch auger, or where hard stràta are encountered a churn drill can be used. Each well should be located so that it will come near the end of a tile; it is then connected with the line by chipping out one end of the tile with a wrench, so as to leave a hole about 2 inches in diameter over the well. All wells must be connected, regardless of whether they flow or not, for they may flow later.

Where the banks of the trench stand up well, the tile where wells are desired should be left with but little blinding over them; after the line is completed a tile can be taken up at each of these places and the well installed. In this case the wells can be placed directly beneath the tile. In trenches where the banks will not stand, it becomes necessary to drill the wells as the tile laying progresses, and they should be placed a few inches to one side and connected with the opening in the tile by placing a half tile over the well. They should not be placed directly beneath the tile, for the sediment washing down from the construction work above is apt to fill up the weak or non-flowing wells.

COST DATA.

Where drainage systems have been installed wholly or in part by the individual landowners, itemized records of expenses incurred generally are not obtainable. However, it is believed that the tracts from which the following data were obtained are fairly representative of conditions as ordinarily encountered in this type of drainage; consequently the unit costs may be assumed to indicate fairly what may be expected in excavating in this sort of material by hand labor.

With labor at $0.25 per hour, actual unit costs for excavating, laying tile and back-filling trenches in shale ranging from 6 to 7 feet in depth averaged $0.12 per linear foot on four small projects aggregating a total of 4,430 feet of trench. A contract job of 2,768 feet of 7-foot trench was let for $0.20 per linear foot, while another job of 5,600 feet, running 6 feet in depth, was let so as to average about $0.11½ per linear foot. These figures do not include the cost of boring relief wells in the bottoms of the trenches. However, taking the work as a whole, this need not increase the cost by more than an average of $0.02 per foot, as there are nearly always some portions of trench on any job in which the relief wells are not essential. The cost of boring the relief wells probably averages about $0.05 per linear foot of well where the depth below the bottom of the trench runs from 8 to 16 feet. Where the depths vary from 16 to 25 feet the cost per foot of well may run as high as $0.10, especially if much sand rock, lime rock, or other hard material be encountered that renders necessary the use of a drill.

The acreage costs of drainage of the affected portions of those projects referred to in this bulletin have been high. This is due in part to the relatively high cost of trenching, but the chief reason is the frequency of drains required, as will be noted by referring to the maps of the several tracts. Based on the actual affected areas, the costs have ranged from $13 to $100 per acre. Almost invariably, however, at the time of drainage the trouble was spreading rapidly, so that the cost in most instances should in all fairness be distributed over the area afforded protection as well as over that directly benefited. As a matter of fact much of the real value of the drainage of shale lands is the benefit that accrues from arresting the development of the trouble. This is especially true because of the very serious alkali problem that results when the lands are allowed to remain in a water-logged condition for any considerable length of time. Once the alkali salts have accumulated in the soil to an extent that renders the land wholly unproductive, it becomes very difficult to bring the land under satisfactory cultivation again. Essentially, then, the most practical way to make this type of drainage both economical and satisfactory is to install the drains at the very first indication of trouble.

EXAMPLES OF METHODS.

EXAMPLE I.

The area of very wet land as indicated on the map in figure 2 aggregates about 22½ acres. Much of this was actually covered with water, and in but few places was it more than two feet from the ground surface to water. These 22½ acres by no means represent

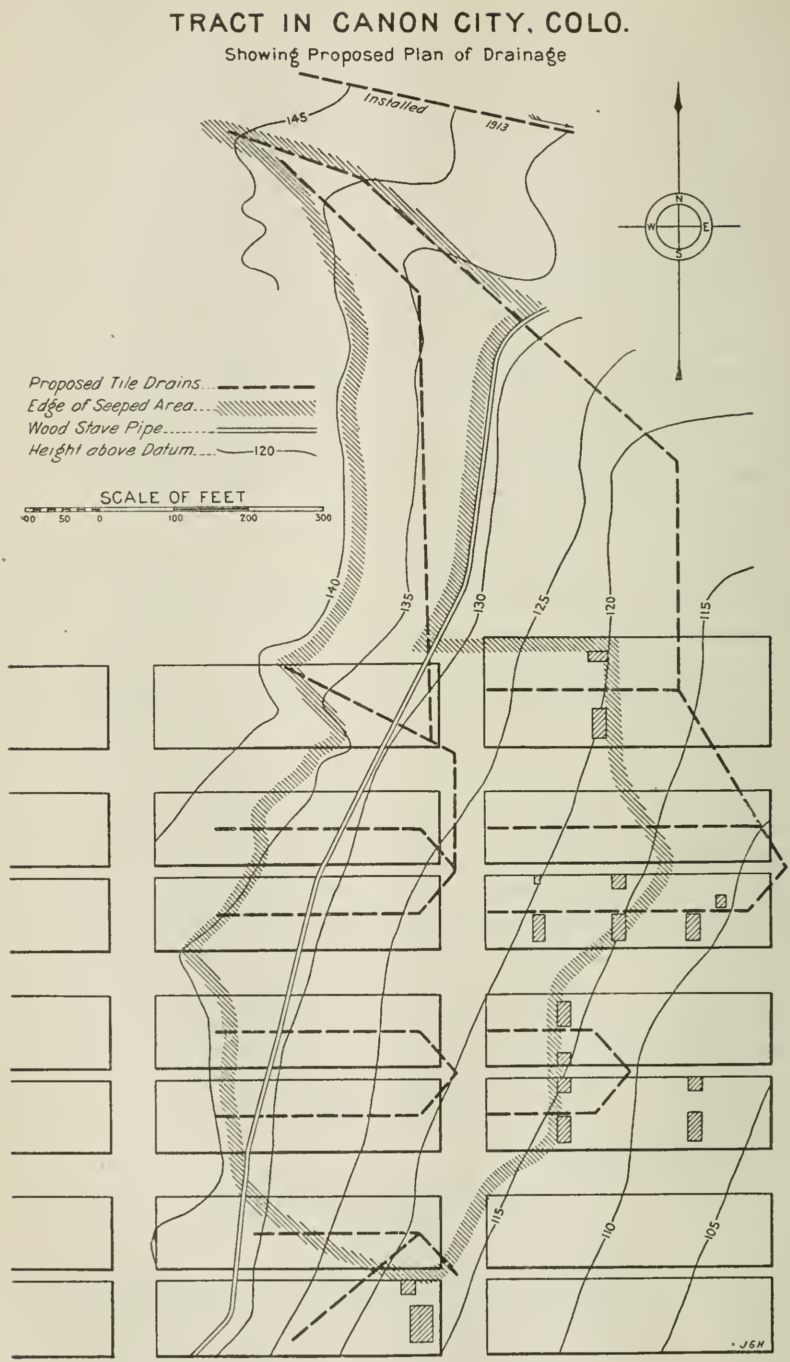

FIG. 2.—Tract near Canon City, Colo., showing proposed plan of drainage.

the total acreage affected by seepage water, as all of the lands immediately adjoining were becoming affected. The surface soil is mostly a dense blue adobe and the subsoil shale which in some cases approaches the surface, although generally it is at a fairly uniform depth of from 3 to 5 feet below. Much of the shale is a flakelike material that has been washed in. This shale formation comes under type No. 2 (p. 3), and constitutes a part of the pressure fold which is west of the tract.

The source of the seepage water was thought by the residents to be the irrigation canal which ran through the wet area and, accordingly, a wood-stave pipe was installed, as indicated in figure 2, to prevent seepage from this canal, but conditions became worse soon after its installation. This indicated that the open canal had been an actual benefit in this particular case in that it had carried away part of the surface water. In any event, the canal could not have been the source of all the water, since the seepage area was well defined for a considerable distance above the canal. The land to the south and east of this tract is lower, and the hogback on the west is a very steep, sharp-crested ridge which does not carry water, as a large irrigation tunnel through it near the base proves. The only other possible source is from the north, and in this direction a mile of unirrigated virgin land intervenes. From all indications the water follows the joints formed between the nearly vertical layers of shale which were formed by the uplift to the west. The movement of the water must take place at considerable depth, for there are no seepage areas in this intervening mile.

Since the underlying shale is rather uniform and not characterized by any distinct features of topography, a uniform drainage system was laid out as indicated on the map. Insufficient funds and other reasons have prevented the installation of all of the drains, but 2,768 feet were constructed. They were effective immediately, and the results on that portion of the tract are very gratifying. Some 8-inch tile were used, but most of it was 6-inch. They were placed 7 feet deep, and relief wells were installed where the solid shale formation was encountered. The work was done by contract and a considerable portion of it was difficult, as it was necessary to use cribbing.

EXAMPLE II.

This is a 10-acre tract of which not over one acre was affected (fig. 3). The source of the damage was the large amount of irrigation water applied on the lands to the northwest near the rim of the valley, in which the soils are comparatively porous. The soil on the tract is very dense adobe. At the time of drainage the land was in fruit trees and a few of the trees were dead on the affected area.

The wet spot became noticeable in the summer of 1913 and by the following summer had increased considerably. There was not much alkali present, but the ground was very wet.

A prominent shale ridge outcrops across the north and east sides of this tract. A deep arroyo at one time extended across the tract

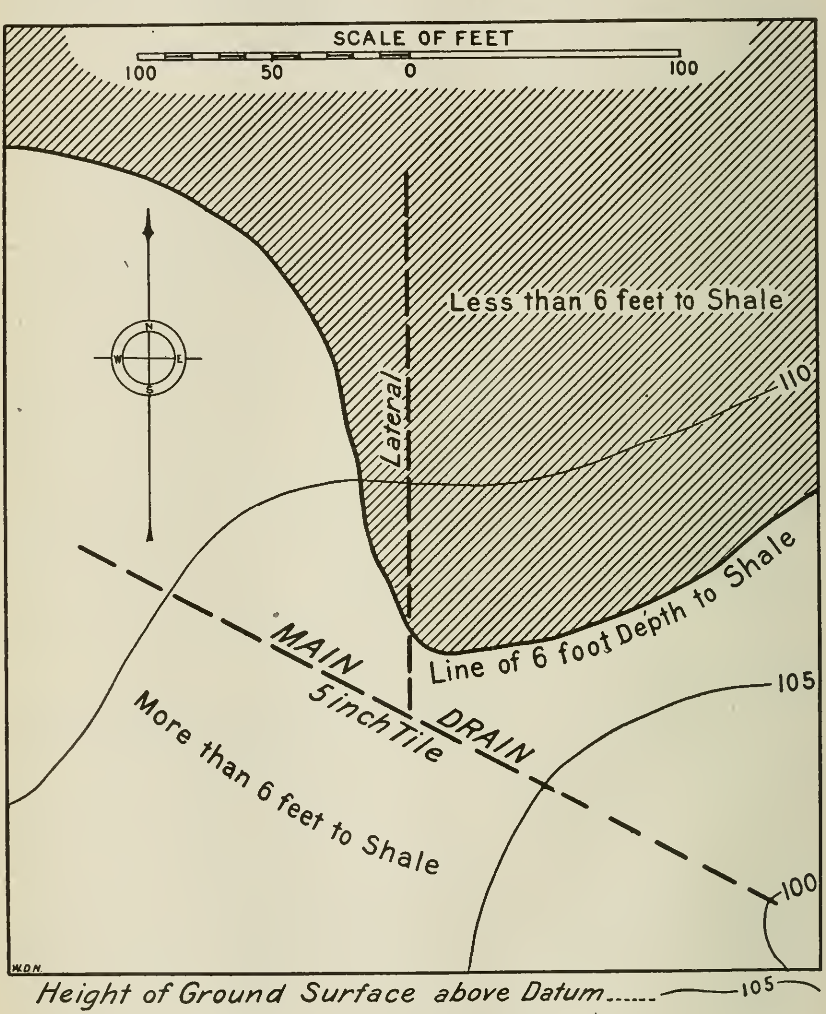

FIG. 3.—One-acre tract near Canon City, Colo., showing plan of drainage.

in the bottom of the shallow draw in which the affected area is located. This was filled in when the land was leveled. It is believed that this had much to do with the development of the seepage, for not only was the natural drainage afforded by the arroyo thus shut off, but the earth filled in became more dense than the natural soil and offered greater resistance to the movement of the ground water. A careful subsoil examination indicated that the seepage water had two sources of supply, the main one being an underlying shale ridge coming in from the north. This ridge is not sharply defined, but is broad and flat, being a part of the larger and exposed shale ridge mentioned above. The other source of supply seemed to be the shallow draw.

The system was laid out as shown in figure 3. The main line runs up the draw, following as closely as possible the edge of the fill next to the seepage area. The most important part of the system is the lateral, 200 feet long, which follows up the shale ridge. Considerable difficulty was encountered in constructing the main line, but in the shale construction was less difficult. In this line about 12 holes were bored with a 2-inch auger. The initial flow in them was strong, and they spouted above the bottom of the trench. This discharge gradually decreased, but the wells still furnish nearly all of the flow obtained in the small system. After a few months the surface of the affected area became so dry and hard that it was difficult to plow.

This tract is a good example of drainage for prevention. The drains were installed before the affected area had spread and before the land had become highly impregnated with salt, and as a result the land was easy to reclaim. If the condition on this tract had not been attended to at once there is little doubt that it would have spread over most of the tract, and the soil would have become so filled with alkali that it would have required two or three years of washing and careful farming, with little or no returns, to reclaim the land. Furthermore, it would have been necessary to install many more drains. That this is a logical conclusion can be deduced from the quality of the drainage water developed by this system as indicated by analysis J in Table I.

EXAMPLE III.

This tract slopes to the southeast as indicated in figure 4. The soil is a dense adobe. Small spots of alkali appeared about four years ago. The steady rise of the water table and the consequent accumulation of an excess of alkali at and near the surface was gradually killing out the alfalfa. With the exception of the southwest corner, all of the alfalfa was in poor condition. At the time of the preliminary examination there were large spots that produced no alfalfa at all, and the water table was practically at the surface which was covered with a thick crust of alkali in which sodium sulphate predominated. There were no indications of black alkali. There were two main alkali spots. One strip extended north and south through the middle of the tract and was broader at the south end, where a bunch of tulles were growing. The other spot, which was very wet, was at the northwest corner and extended across the road to the west. The road was impassable and a large portion of the tract on the west was affected.

From a large number of borings the topography of the underlying shale was determined as indicated in figures 4 and 5. Shale was found near the surface on three-fourths of the tract, but no shale nor water could be found at a depth of 12 feet at the southwest corner, and the alfalfa there was in good condition. The strata of the shale underlying the tract are nearly vertical and badly broken.

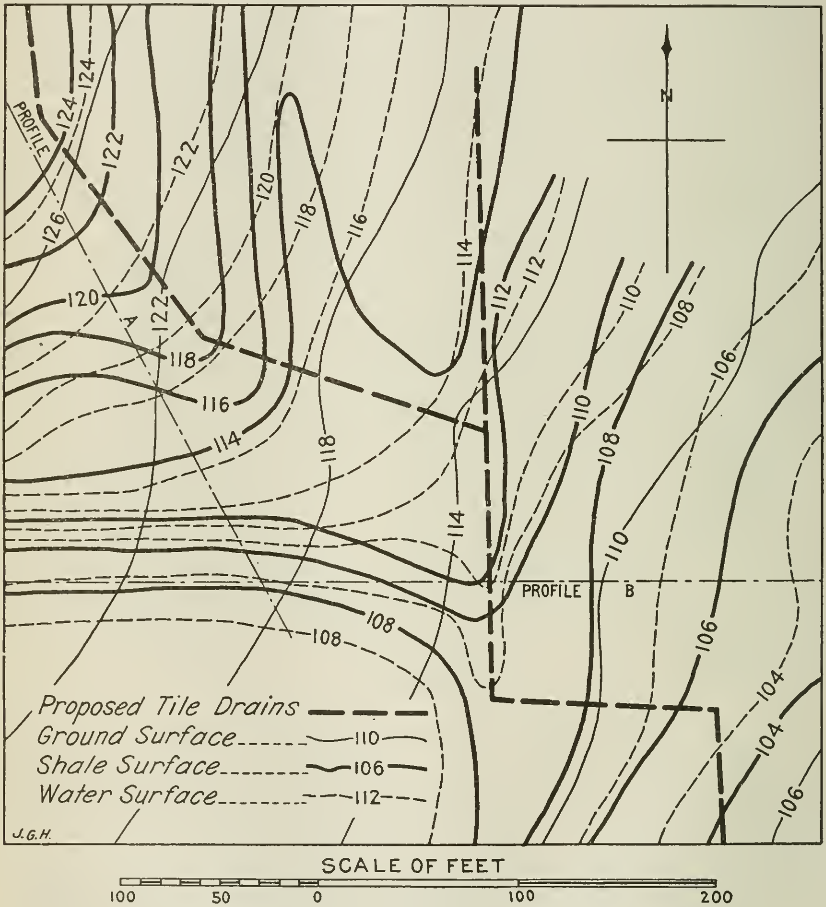

FIG. 4.—Four-acre tract near Canon City, Colo., showing plan of drainage.

The shale is comparatively soft, from dark blue to reddish brown in color, and carries considerable water. The water apparently comes from the north, following along the joints in the shale strata, although it is believed that the extreme wet condition of the northwest corner is due in part to the movement of the water in the top soil from the tract to the west, which also is very wet. The underlying shale ridges on this tract are not well defined; they are broad and flat. A rather broad shale ridge comes in at the northwest corner and extends to the center of the tract and thence south, where it is well defined. Along these ridges the water table always was nearest the surface.

Several years prior to the draining of this tract a drainage system was installed on the tract south and east. Four-inch tile were used and branches were placed at frequent intervals, but the depth was not much over 4 feet. While the surface of the ground is not wet,

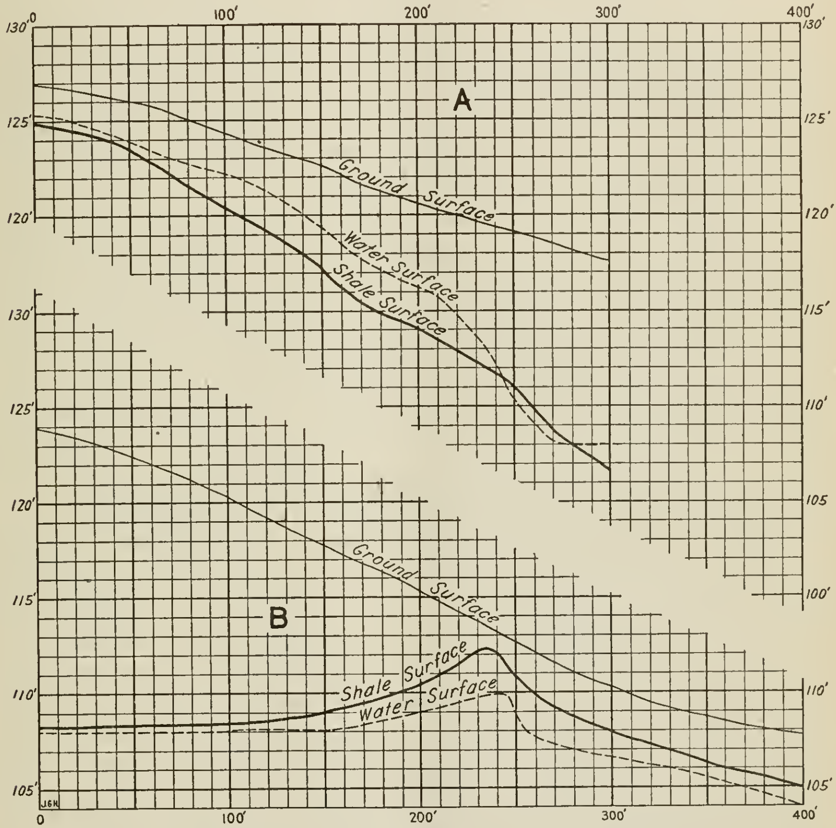

FIG. 5.—Typical profiles across tract shown in figure 4.

the trees are beginning to show the effect of a high water table and a number of them are already dead. One of these 4-inch tile branches was used as an outlet for the system under discussion in order to cut down expenses, but it would have been better if an outlet of larger tile had been constructed.

The system was laid out as shown in figure 4, an attempt being made to follow the shale ridges. The depth of the system ranges from 6 to 7 feet. As nearly all of the trenches were in shale, very little difficult construction was encountered. In some places the banks of the shale trenches broke off in large pieces and it became necessary to put in occasional braces to hold them. The drainage of this tract could have been better accomplished by immediate drainage of the entire affected area, which includes several acres on the west, but the owner of the latter tract was not ready at that time. While the tract is not yet free from alkali, the surface has become fairly dry and the rushes have disappeared; however, the road on the west side of the tract still remains impassable.

EXAMPLE IV.

Twenty years ago the farm shown in figure 6 was considered one of the best in the vicinity of La Junta, Colo. The gradual rise of the water table and subsequent accumulation of alkali salts have seriously damaged 700 acres of land in this vicinity. Much of it is not farmed at all and none of it yields profitable crops.

The tract is located in a circular basin which contains approximately 3,000 acres, all of which is irrigated. Just below this tract the basin narrows down to a draw which bears north about $1\frac{3}{4}$ miles to a creek. This draw is the only feasible drainage outlet. There are two irrigation canals running through this district. More than 78 second-feet are furnished to the land in this basin. Water runs during the entire year in one of the canals. The irrigation season is very long, and many people practice winter irrigation, which contributes largely to the damaging seepage water. The quantity of water used is no doubt considerably over 4 acre-feet per acre.

The soil varies from a fine sandy loam to a sandy adobe. Gypsum is very abundant. It occurs in partly disintegrated crystals and flakes, often very nearly pure and imparting a mealy character to the soil. This constituent seems to have been derived largely from decomposition of the shales. A layer of gypsum always was found just above the shale and it seemed to carry water freely. On the south half of this tract, near the surface, is found a series of alternating beds of limestone and calcareous shales. The shales are very compact, and borings showed that while the upper layers, which had partly disintegrated and contained gypsum crystals, usually were moist, they became very hard and dry with depth. The water-carrying capacity of these shales may be considered as negligible.

The idea is prevalent among the people of this section that the trouble is due to loss from the irrigation canals and that the proper method of drainage is to construct an intercepting line just below the canal. While these canals doubtless contribute to the underground water, most of it is due to loss from laterals, to failure to take care of waste water, and to the use of excessive quantities of irrigation water. The injury due to excessive irrigation lies not only in the swamping of large areas of lower lands, but also in the ruin of large tracts from the accumulation of alkali salts on the surface.

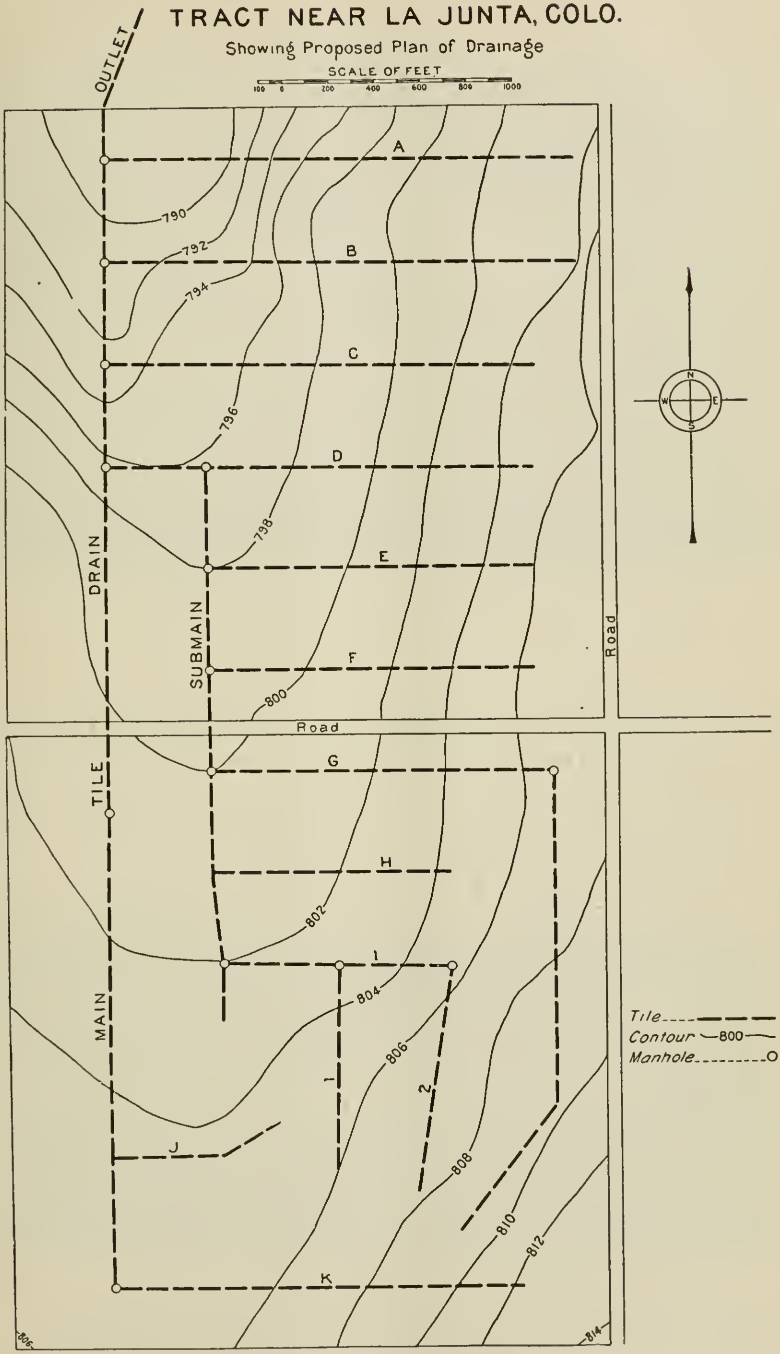

FIG. 6.—Tract near La Junta, Colo., showing proposed plan of drainage.

The first point to be taken up in the reclamation of this tract is the disposal of the waste water. The soil on the north half is mostly Fresno fine sandy loam, and the conditions are fairly uniform. The method of relief drainage should be used with six branches of 6-inch tile, running east, about 400 feet apart. The drainage of the south half is a more complex problem; a combination of the relief and intercepting methods should be used. Branches "G" and "K" (fig. 6) are intercepting drains. The peculiar arrangement of the other lines is due to the irregularities in the seepage conditions and to the fact that limestone is found near the surface in some places, as an attempt was made to locate the lines so as to prevent rockwork in the trenching. The average depth of the system should be not less than 7 feet, and in no place should a line be less than 6 feet deep.

EXAMPLE V.

An investigation was made on this tract during the early part of the year 1915. A large number of test wells were drilled and a topographic map of the underlying shale and water surface was made, as shown in figure 7. A pronounced shale ridge was found, and there was a marked resemblance between the shale and water contours (see figs. 7 and 8). As figure 8 indicates, the point of the shale ridge was discharging water into the soil beyond. At the time of the examination only a small portion of the alfalfa was affected between the point of the underlying shale ridge and the south fence line. A tile line reaching well into the shale point was staked out, as shown on the map. The owner was unable to install the line at that time, and the tract was visited again in the early part of 1916, when it was found that the affected area had spread over the entire south half of the tract.

EXAMPLE VI.

It is not known just when trouble first became apparent on the 40 acres shown in figure 9, but from all indications it must have been at least three or four years before the time of making the preliminary examinations in the spring of 1913. At that time about 20 acres, extending north and south through the center of the field, were very wet and badly alkalied (Pl. VII, fig. 2). The whole 40 acres were at one time in alfalfa, and on both sides of the alkali strip alfalfa was still growing, with the stand about normal except immediately adjacent to the wet land, where it was thinner and more spotted.

The land to the north and west is higher than the tract under consideration, especially to the west, just across the road, where it rises to an elevation some 20 or 30 feet higher and culminates in a little ridge running north and south. Excessive irrigation on this ridge has been one of the chief sources of the seepage water, al-

FIG. 1.—OUTLET OF DRAIN, SHOWING QUANTITY OF WATER DEVELOPED.

FIG. 2.—ALKALIED CONDITION OF THE LAND.

YOUNG PEAR ORCHARD, WET AND ALKALIED ALTHOUGH ALMOST ON THE BANK OF A WASH 12 FEET DEEP. (SEE EXAMPLE VII, PAGE 34).

FIG. 1.—PRIOR TO DRAINAGE, ORCHARD WAS DYING AND LAND NOW IN ALFALFA WAS BARREN.

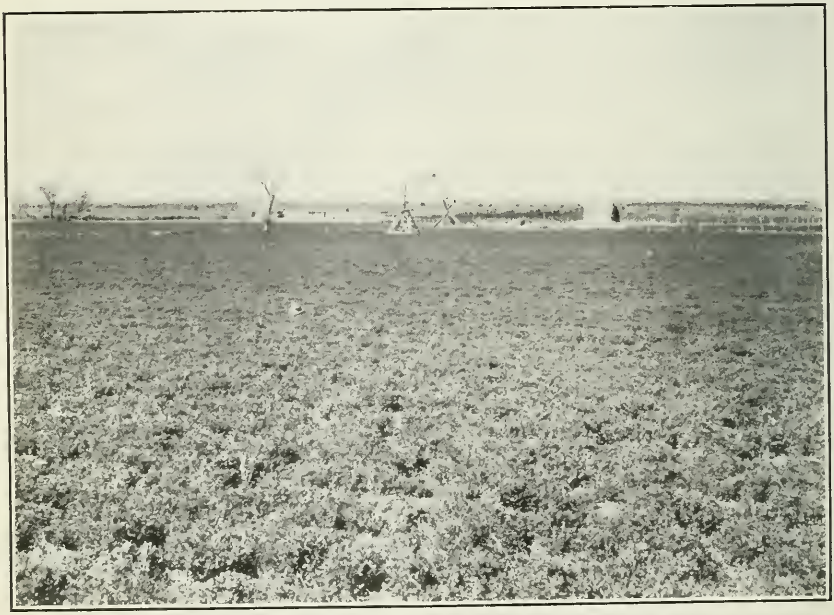

FIG. 2.—DRAINED SHALE LAND UNDER CULTIVATION.

RESULTS OF PROPERLY INSTALLED DRAINS ON SHALE LAND.

FIG. 1.—DRAINED SHALE LAND UNDER CULTIVATION.

FIG. 2.—ALL THE IMPROVEMENTS SHOWN HAVE BEEN MADE SINCE A DRAINAGE SYSTEM WAS INSTALLED.

RESULTS OF PROPERLY INSTALLED DRAINS ON SHALE LAND.

though poorly constructed waste ditches and a small reservoir to the north have contributed.

Lateral A, as indicated in figure 9, was installed with the view of intercepting the seepage from the west, while the main tile drain

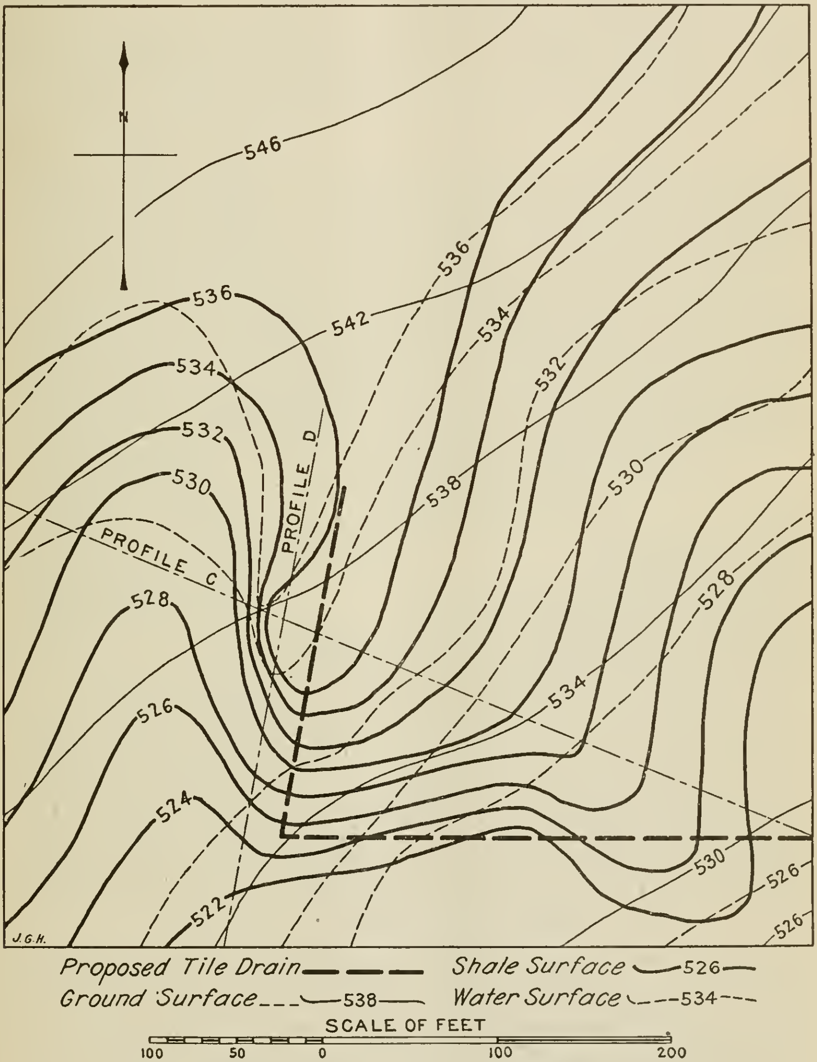

FIG. 7.—Five-acre tract near Canon City, Colo., showing plan of drainage.

was constructed next to take care of the waste water from the north and was indispensable for this purpose. However, so far as any actual benefits from drainage are concerned, the results from both of these drains were negligible and offer the most convincing evidence presented by any of the examples in this bulletin of the failure of both the relief and the intercepting principles of drainage as ordinarily understood when applied to shale lands—this notwithstanding the fact that both of the tile lines were 6 feet deep and that a complete system of relief wells was installed in conjunction with lateral A. Particular attention is called to the system of drainage as it was worked out later. This embraces branch A–1 and laterals B and C with their branches. Branch A–1 follows closely the lower margins of a broad shale point, only one edge of which is shown on the map. Branches B–1, B–2, and B–3 are located up the back-

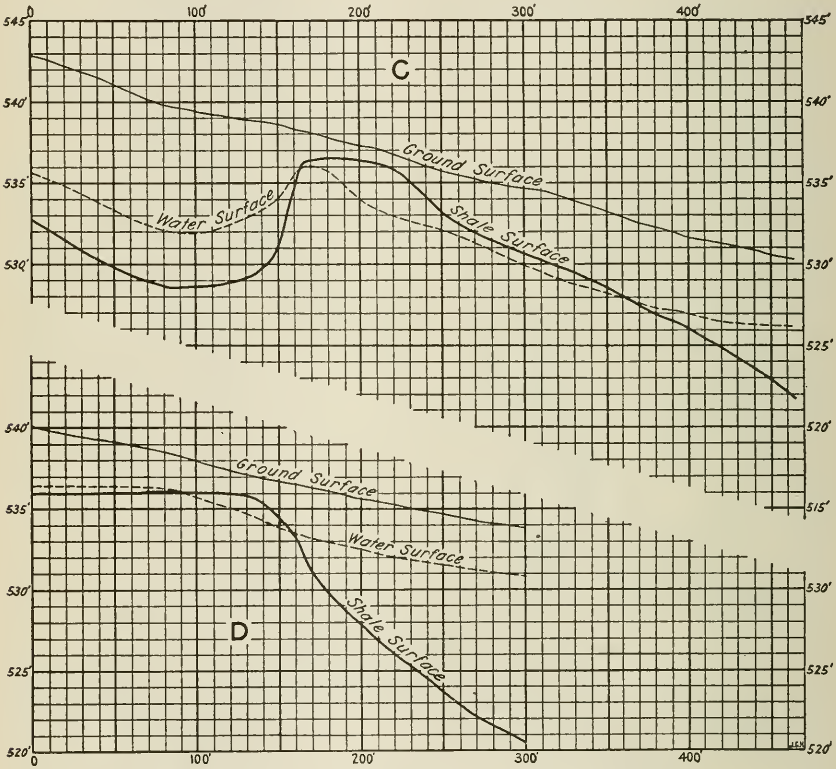

FIG. 8.—Typical profiles across tract shown in figure 7.

bones of three very narrow points. Branches C–1 and C–2 are located up the two sides of a broad shale point. Relief wells were installed every 15 to 20 feet along the tile lines in the shale points. This method of intercepting the seepage from the shale has been entirely satisfactory and has afforded all the relief expected. The quality of water developed by this drainage system has been above the average in salt content and is represented by sample C in Table I.

EXAMPLE VII.

The project shown in figure 10 is of peculiar interest in that the existence of the wet spot almost on the bank of the wash, 12 feet deep (Pl. VII, fig. 1), illustrates very clearly that a drain improperly located may be absolutely worthless, no matter how deep. The project is also interesting owing to the extreme rapidity with which the seepage trouble developed. In the season of 1913 about 4 acres near the center of the tract, upon which a young pear orchard was

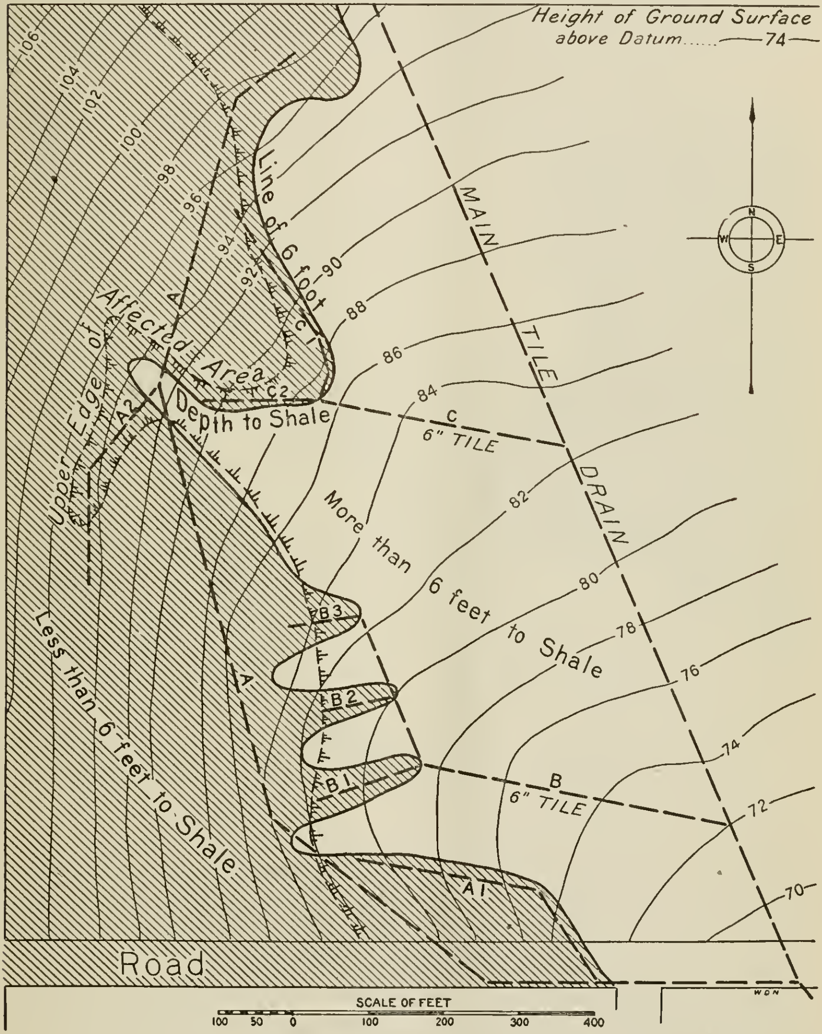

FIG. 9.—Forty-acre tract near Canon City, Colo., showing plan of drainage.

growing and which was seeded to alfalfa, became so wet that the first crop of hay was harvested with difficulty. By midsummer water had risen to the surface of the ground and was running off through the irrigation furrows and waste ditches, and by late fall many of the pear trees and most of the alfalfa were dead (Pl. VII, fig. 2).

The land immediately northwest, north and northeast is irrigated. It is higher than the tract under consideration and is underlain by shale that outcrops in many places. As indicated on the map, a shale ridge extends from these higher irrigated areas, and the trouble first became evident over the backbone of this ridge and near the point. In designing the drainage system one tile line was located so as to follow up the backbone of this ridge and one along each

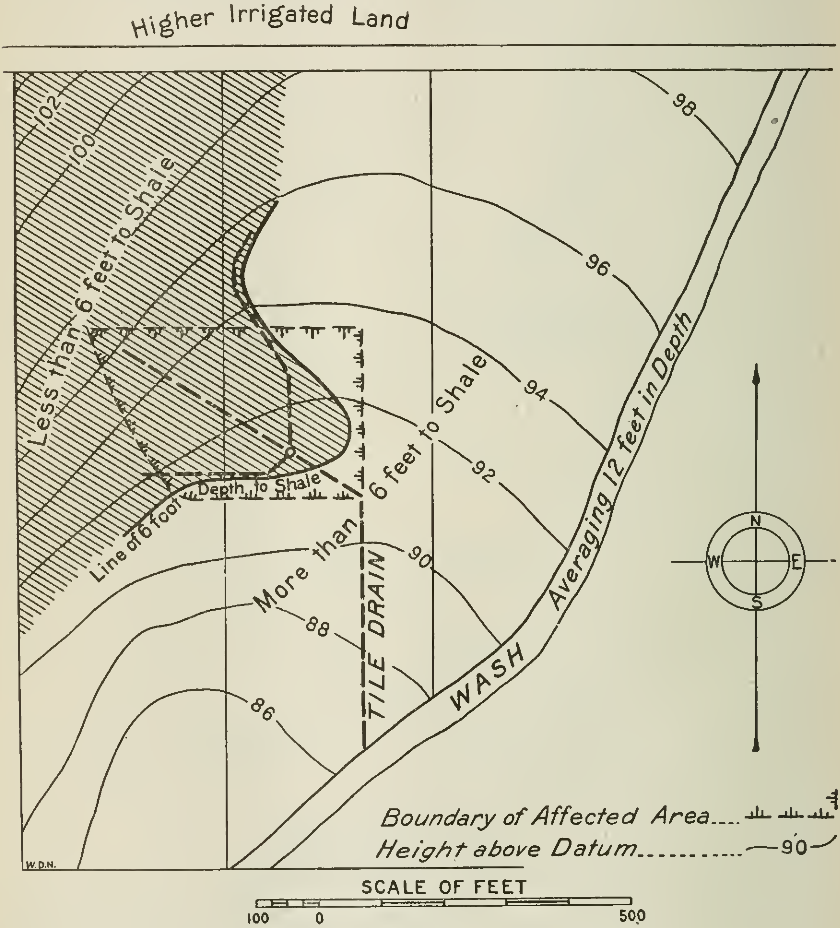

FIG. 10.—Twenty-acre tract near Grand Junction, Colo., showing plan of drainage.

edge of the ridge. The system was installed in the spring of 1914. The tile were put at an average depth of 6 feet and connected with relief wells 2 inches in diameter that were bored into the shale to depths of from 6 to 12 feet below the bottom of the trench, where the water-bearing strata were encountered. One of these wells, of which there are 35, was installed every 17 feet, and practically the entire flow of water discharging at the outlet of the tile system comes from them.

For the first year the discharge from this drainage system averaged 43 gallons per minute, or about 0.095 of a cubic foot per second, practically the entire quantity of which was collected by the 35 relief wells in about 1,000 feet of tile. The hydrograph shown in figure 11 was plotted from measurements at the outlet of the system made at irregular intervals during the first 14 months after the drains were installed. It indicates the discharge in gallons per minute and shows a marked seasonal fluctuation. As determined from this hydrograph, the flow from the relief wells has averaged 1.2 gallons per minute per well. The quality of the drainage water is indicated by analyses F and G in Table I.

Considering the size of the affected area, the quantity of water developed is unusually large for this type of land, and would indicate the source of supply to be either leakage from the canal one-half mile north or the seepage of water supplied on not less than 20 or 30 acres of the higher-lying lands in the neighborhood. In either case, before reaching the drains the water must pass through shale for several hundred feet. While the upper $3\frac{1}{2}$ feet of soil on this tract has been dried out thoroughly, the efficiency of the drainage system would have been increased by installing the main drain up the backbone of the shale ridge 8 feet deep instead of 6; moreover, another lateral drain with relief wells is needed, beginning 400 feet north of the outlet of the system, where the main tile line

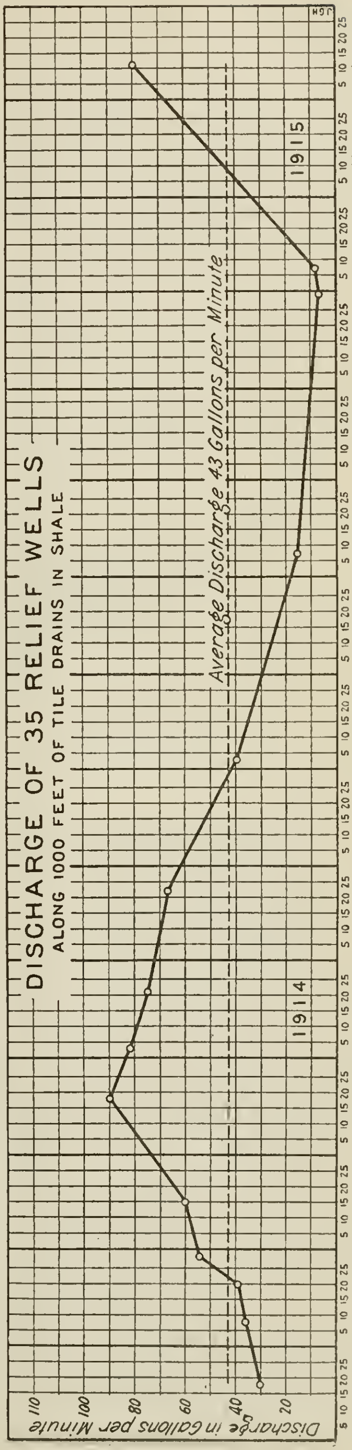

FIG. 11.—Hydrograph of discharge from drainage system shown in figure 10.

makes its first turn, and running a little east of due north for about 200 feet.

EXAMPLE VIII.

The tract shown in figure 12 exemplifies the method of drainage as applied where a broad, flat shale ridge contributed the seepage water. Lateral A was installed two seasons prior to drilling the relief wells, and no benefits whatever resulted from the drain. Both sides of the trench were very wet almost to the surface of the ground wherever the trench was opened for the purpose of connecting the relief wells with the tile lines. After the wells were installed a marked improvement became apparent almost immediately and the tract was put

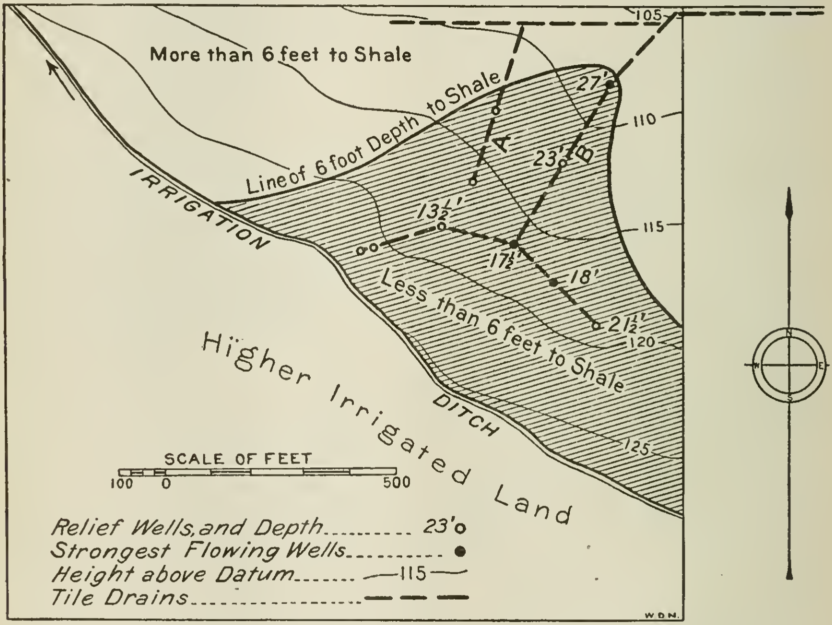

FIG. 12.—Forty-acre tract near Montrose, Colo., showing plan of drainage.

under cultivation the following season with satisfactory results. The depths of the most effective relief wells are indicated on the map. Attention is called to the distances between wells, from 150 to 200 feet, which are unusually great. Generally speaking, this project was one of water-logging rather than of alkali. The analysis of the water discharged at the outlet of the tile system after completion is represented by A in Table I.

RESULTS OF DRAINAGE.

Drainage of any type of agricultural land is successful only to the extent that the land increases in productivity after the completion of the drainage system. As illustrative that adequate drainage of shale lands will fulfill this requirement, attention is called to Plates

VIII and IX. All the lands represented had become water-logged, alkalied, and unproductive. They have been reclaimed by drainage to the extent that the crop yields are normal again. Before drainage the orchard shown in the background of Plate VIII, figure 1, was dying, while the land now in alfalfa was barren. Since the completion of the drainage system no trouble has been experienced on this tract. All the improvements shown by Plate IX, figure 2, were made after the drainage system was installed and the benefits to the land evident to the owner.

CONCLUSION.

Outcroppings of shale and lands immediately underlain by shale, as treated in this bulletin, are found in northern New Mexico, in southeastern Arizona, in large areas of Colorado, in the eastern portion of Utah, in the extreme eastern part of Idaho, in Wyoming, Montana and in the western parts of Nebraska and the Dakotas.

Shale is an important factor in the movement of underground water, especially in those areas where uplifts and displacements have occurred.

Three different ways by which shale becomes a factor in the movement of seepage water have been considered: (1) Over the top of the undisturbed and impervious strata; (2) between the layers; and (3) through joints, faults and cleavage planes.

The minor features of the surface of the underlying shale are frequently quite irregular and are masked by the overlying soil. They can be determined only by soil borings.

The source of the seepage water is deep percolation, resulting from irrigation and from seepage losses from canals and laterals.

Artesian conditions exist usually where the seepage water moves through the shale, although the pressure may be low owing to a large number of areas of leakage in the confining medium.

There is a relation between the seepage areas and the topography of the underlying shale. The affected areas usually occur near shale ridges and points. This is due to the fact that there is greater porosity in the shale ridges than in the deeper zones, the former having sustained the effects of weathering and therefore being more shattered and fractured and the joints more open and greater in number. Furthermore, the soil covering is shallowest over the ridges.

The deeper zones carry most of the water, owing to continuity and greater area of cross section, and the general movement of the water is parallel with the main jointing systems of the shale.

Practically all the shales run high in alkali salts, and the seepage waters leach out large quantities. Consequently many of the waters discharged from drainage systems in shale carry a salt content as high as 2 and 3 per cent, in which are many nitrates. Because of this condition of the seepage water the soils of shale lands that have become water-logged develop a severe alkali problem rapidly.

The drainage of shale lands can not be accomplished by ordinary methods of drainage, due to the movement of the water through the shale under pressure and also to the extreme retentiveness of the overlying adobe soil.

The three essential factors for successful drainage of shale lands are: (1) Proper location of drains, (2) sufficient depth, (3) relief wells.

Drains must be located so as to tap the contributing shale features, such as ridges, points, knolls, etc. To so locate drains necessitates careful and complete preliminary examinations.

The amount of shale reached and the amount of water developed are augmented by increasing the depth of the drains. These depths never should be less than 6 feet, and generally depths of 7 and 8 feet and greater are essential to success.

A system of drainage in many of the shales will be incomplete and unsuccessful without relief wells.

The area of influence of relief wells is small; this necessitates that they be closely spaced—in many cases 5 or 6 to 100 feet of trench.

The most efficient depth for the wells has been found to range from 6 to 20 feet below the bottom of the tile drain.

The major portion of the water developed by most of the drainage systems in shale comes from the relief wells.

A diameter of 2 inches has been found to be sufficient for the relief wells, and in most of the shales they have been installed with the soil auger. Frequently, however, hard strata require the use of a churn drill.

For trenches in shale ranging from 6 to 7 feet in depth, and with labor at $0.25 per hour, unit costs for excavating, laying tile, and back-filling, together with the cost of installing the relief wells, have ranged from $0.12 to $0.25 per linear foot of trench. This does not include the cost of any material for the drains.

The acreage costs of drainage of the lands referred to in this bulletin have ranged from $13 to $100 per acre for the area actually affected.

Once seepage trouble has developed in shale lands, the affected area increases rapidly. The quantity of the alkali salts at or near the surface of the ground also increases rapidly in water-logged lands of this type. As a result of these conditions, the drainage problem and the one of removing the excessive salts are simplest, the construction most economical, and the results most satisfactory, if the drains are installed at the first indication of trouble.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 503

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A. C. TRUE, Director

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TURNIPS, BEETS, AND OTHER SUCCULENT ROOTS, AND THEIR USE AS FOOD.

By C. F. LANGWORTHY, *Chief, Office of Home Economics, States Relations Service.*

CONTENTS.

INTRODUCTION.

The succulent roots, so called because water (juice) makes up so large a part of their edible substance, include such common and long-known vegetables as turnips, parsnips, radishes, carrots, salsify, beets, celeriac, onions, and garlic. In the same general group belong also a few roots which are used as condiments or spices rather than for their food value, the most common being ginger and horse-radish.

The succulent roots which are grown as garden vegetables have undoubtedly all been developed from wild forms, though, as is the case with many other plants which have been under cultivation for centuries, the wild forms of most of them are not definitely known. It can be said with certainty, however, that as they have come under cultivation the roots have increased in size, the texture has become less tough, and the flavors have been modified. Those here grouped together include such diverse forms as bulbs, roots, stalks, root-stocks, and tubers. It is evident, therefore, that from the botanist's standpoint this use of the term "roots" is not accurate; it has come into use in discussing the matter from a household standpoint doubtless

NOTE.—This bulletin is of special interest to housekeepers and to home economics extension workers, teachers, and students. It summarizes data regarding the nature, uses, and food value of succulent roots.

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for the lack of a more exact yet simple word, and is here used because of its convenience as a general descriptive term.

As a whole, "succulent roots" and "starchy roots,"[1] the two great groups into which edible roots are commonly divided, together constitute one of the most important sources of food.

The succulent vegetables owe their popularity in considerable measure to their good keeping qualities. After harvesting in the late autumn, they will keep in a cellar, or other cool storage place, for a long time in reasonably good condition, though as the season advances they may become somewhat tough and strong in flavor. It is a common custom in the Northern States to store such vegetables in sand rather than in bins or boxes, and some sorts, such as parsnips and oyster plant, are frequently left in the ground and dug in early spring. In the parts of the United States where the weather is mild and yet too cool to permit growth, this is an especially common method of keeping winter vegetables, for it is possible to dig them at almost any time during the winter.

Now that cold storage and improved methods of transportation have made it easily possible to secure a greater variety of vegetables at all times of the year than was formerly the case, the stored root vegetables are relatively less important. This does not mean that their use is likely to disappear, but rather that the northern markets are being supplied also with more delicate varieties; for instance, small tender beets, which many would prefer to the larger and tougher ones commonly stored for winter use. In southern markets one can obtain such vegetables fresh a good part of the year.

The usefulness of root vegetables is not limited to their underground portions, since in many cases the leaves and stems, when young and tender, are good as potherbs. Most commonly used are beet tops and turnip tops, but radish and horse-radish leaves also make good "greens," especially for mixing with greens of milder flavor, and occasionally carrot tops are also used for this purpose. The careful housekeeper who buys beets and turnips by the bunch will save and use the tops for greens. If she has a garden she will use the young plants when they are thinned out, and may also often get a dish of greens by picking tender leaves here and there from her garden bed of beets or turnips. The young green tops of onions are much used for seasoning and are also tender and palatable when cooked as a vegetable. Celeriac tops, too, are useful as a seasoning.

Most of the common succulent vegetables—turnips, beets, parsnips, carrots, etc.—are biennial plants, and if by any chance the roots re-

[1] The nutritive value and uses of starchy roots have been discussed in U. S. Dept. Agr. Bul. 468 (1916). Recipes for preparing such vegetables for the table will be found in U. S. Dept. Agr. Farmers' Bul. 256 (1906).

main in the ground and are not killed, they will start to grow and send up their flower stalks and bear seed. This is, of course, the purpose for which nature designed the reserve material stored up in the roots which we use as food. This second-year growth may be turned to advantage for the table; a surplus of turnips, too wilted for table use, may be planted out in spring and, while the leaves are still tender, will furnish a crop of good greens, or may be added to salads if one prefers.

FOOD VALUE OF SUCCULENT ROOTS.

Many factors may be considered in deciding on the food value of any material, but one which must be taken into account is its chemical composition. When that has been learned, there is a definite basis for discussing its value in supplying the protein essential as a source of nitrogen for use in tissue building and which also supplies energy, the energy-yielding starches, sugars, and fats, the tissue-building and body-regulating mineral matters, and so on. The following table presents these facts regarding the more important succulent roots:

Average composition of succulent roots, tubers, and bulbs.

Kind of vegetable.	Refuse.	Edible portion.						
		Water.	Protein.	Fat.	Carbohydrates.		Ash.	Fuel value per pound.
					Sugar, starch, etc.	Crude fiber.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
Beets, fresh	7.0	87.5	1.6	0.1	8.8	0.9	1.1	210
Beets, cooked	....	88.6	2.3	.1	7.4		1.6	180
Celeriac	20.0	84.1	1.5	.4	11.8	1.4	.8	285
Carrots, fresh	20.0	88.2	1.1	.4	8.2	1.1	1.0	205
Carrots, desiccated	....	3.5	7.7	3.6	80.3		4.9	1,745
Parsnips	20.0	83.0	1.6	.5	11.0	2.5	1.4	295
Salsify, "oyster plant"	25.0	85.4	4.3	.3	6.8	2.0	1.2	250
Black salsify	20.0	80.4	1.0	.5	14.8	2.3	1.0	350
Radishes	....	91.8	1.3	.1	5.1	.7	1.0	135
Turnips, white	10.0	89.6	1.3	.2	6.8	1.3	.8	180
Turnips, yellow (rutabagas)	10.0	88.9	1.3	.2	7.3	1.2	1.1	185
Kohl-rabi	20.0	91.1	2.0	.1	4.2	1.3	1.3	140
Onions	30.0	87.6	1.6	.3	9.1	.8	.6	220
Garlic	....	64.6	6.8	.1	26.3	.8	1.4	620
Potatoes	20.0	78.3	2.2	.1	18.0	.4	1.0	380
Horse radish	....	76.7	2.7	.4	15.9	2.7	1.6	400

As a rule the succulent roots, tubers, and bulbs contain larger quantities of water than the starchy vegetables and consequently have a lower nutritive value, pound for pound. The proportion of nitrogenous material which they contain is low, and of this small amount not more than a third, and frequently only a fifth, is in the form of true protein. As regards carbohydrates, various sugars, pectose bodies, and, in some cases, pentosans, very generally constitute the reserve material which the plants store up instead of the starch, which is the principal carbohydrate in potatoes, sweet potatoes, etc. These facts are brought out clearly in figure 1, which shows the composition of common root vegetables in comparison with bread, and in figure 2, which makes a similar comparison between root vegetables, bread, and milk as sources of energy to the body. As a class these succulent roots are characterized by very marked flavors and odors, the flavor being due in part to the sugar and plant acids, and in part to the small amounts of volatile oils and similar substances which they contain and to which the odors are mainly due. Thus the peculiar flavors of turnips, radishes, onions, etc., are due chiefly to sulphur compounds.

It is not enough to consider protein and energy value in discussing food values. Mineral substances must be taken into account also, since they are essential for body growth and maintenance and for other physiological purposes. The need for iron in making red blood (hemoglobin) and the need for lime in making bone are well-known examples of the necessity for mineral substances. Work done in recent years has emphasized another important reason for supplying mineral matters in the diet, and from vegetable as well as animal food materials. It is now an accepted fact that the body performs its functions best when the tissues and fluids are either neutral or slightly alkaline and that different classes of food materials, after they have been digested, leave the tissues and fluids of the body in different condition, some alkaline, some acid, and may, therefore, be spoken of as potentially acid or potentially alkaline. Many vegetables and fruits, owing to the presence of citric and other similar acids, are not alkaline when eaten but are potentially alkaline, because these acids leave behind an alkaline salt after being burned in the body. Foods rich in protein, such as meat, poultry, fish, and eggs, are potentially acid, because the sulphur and phosphorus which they contain are not completely burned but are partially left behind in the form of so-called fixed acids. It is to neutralize such acid residue that the potash and other salts of alkaline property supplied by fruits and roots and other vegetables are so valuable. Expressed in everyday terms, the results of laboratory experiments show that when the diet contains such foods as meat, eggs, and fish, a generous supply of vegetable foods should be supplied also—an ample justification of the old household custom of serving potatoes, turnips, beets, and other vegetables in abundance with meat.

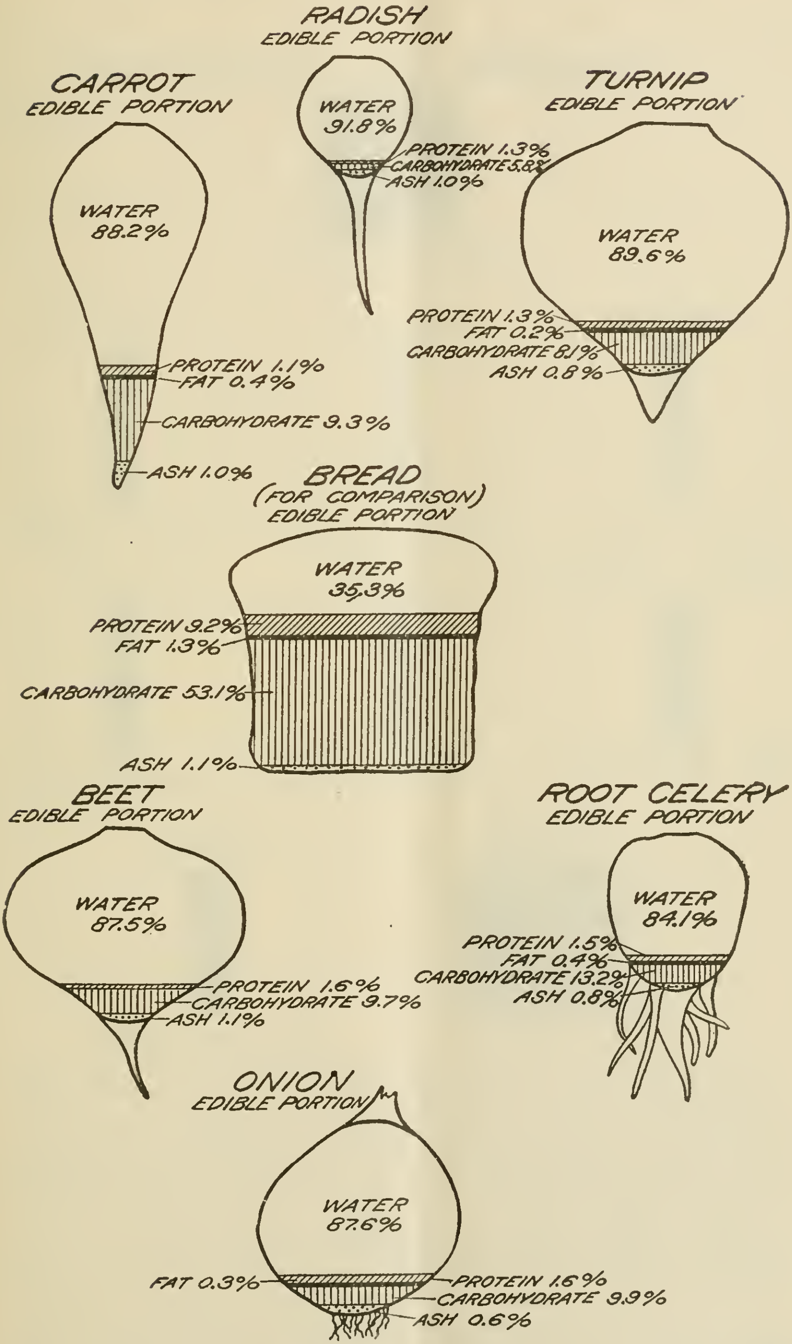

FIG. 1.—Carrot, onion, beet, and other root vegetables compared in composition with each other and with bread.

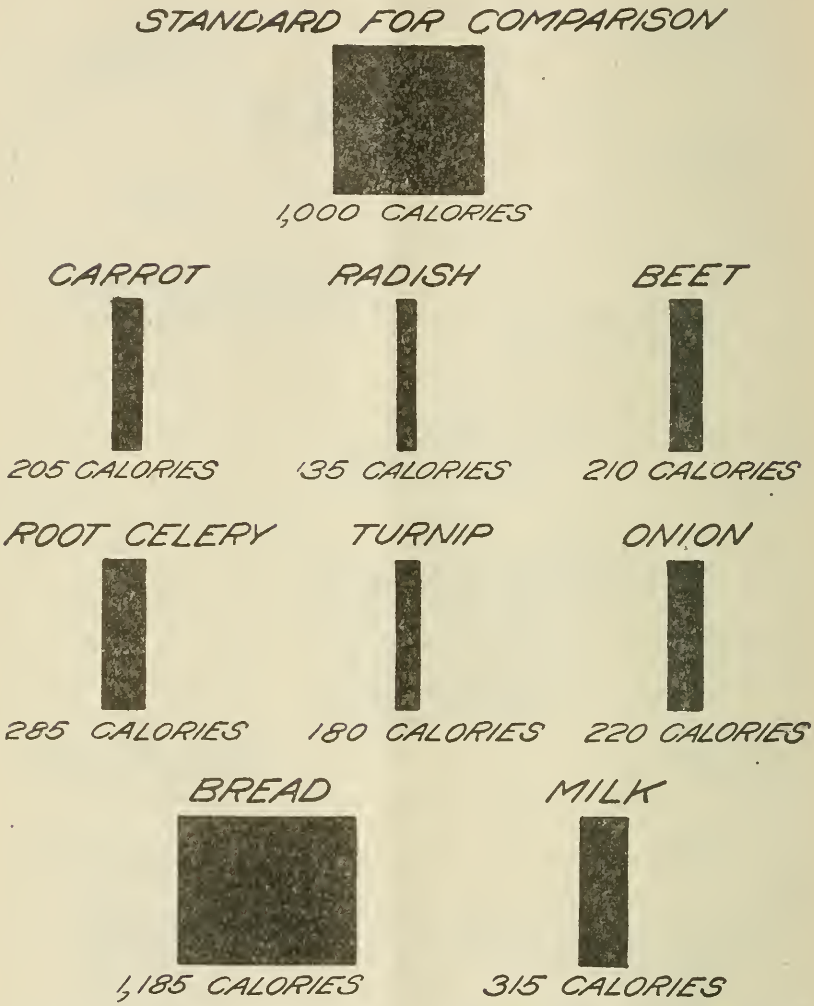

Fig. 2.—Energy value of edible portion of root vegetables per pound. Just as an engine must have fuel as a source of the power it supplies, so the body, which is a living engine, uses its food as fuel to supply the energy for the work it performs. For measuring the energy value of food the calorie is the most convenient unit. It represents in round numbers the amount of heat required to raise 1 pound of water from 0° to 4° F., and equals very nearly 3,087 foot-pounds. If it be assumed that the large square at the head represents 1,000 calories, the amount of energy which a pound of the different succulent vegetables would supply is shown in graphic form by the black rectangles used for comparison. These values are, in general, low as compared with such a food as bread. Nevertheless, the succulent root vegetables as a group contribute materially to the energy value of the diet in addition to furnishing material for the structural needs of the body. They are especially important for the mineral elements they supply, and in this respect rank high in comparison with other kinds of food.

In respect to final alkalinity, beets and carrots make the best showing of the succulent roots and are superior to all our common food materials except some of the green vegetables and fruits. Parsnips and radishes outrank potatoes; while turnips, which stand below potatoes, are yet higher than sweet potatoes.[1]

Though many vegetables are more economical sources of protein and energy than is sometimes realized, they are probably of even greater value for their ash constituents than for the carbohydrates and other organic substances which they contain.

Furthermore, in considering the food value of vegetables, as of fruits, some of which are regarded merely as luxuries, one must not overlook the fact that they possess an actual advantage in enabling us to round out our dietary, as regards both bulk and palatability, without making the protein or energy intake excessive or compelling us to restrict the consumption of foods already in use. It can be said then, that a more liberal use of vegetables is to be encouraged; and if the cost of the diet must be strictly limited, it is often wise to restrict the use of some other food rather than this group. It should not be forgotten, however, that the cheaper vegetables are fully as valuable for the purposes mentioned as are the expensive and out-of-season sorts.

To sum up what has been said regarding the food value of the succulent roots, tubers, and bulbs, they are much less important food materials, when considered from the standpoint of the protein, fat, and carbohydrates which they supply, than are the concentrated cereal foods or even the starchy roots and tubers. They are, however, very valuable in the diet for other reasons. They furnish some nutritive material, and are appetizing and generally relished, and their use often makes palatable an otherwise flavorless dish or meal. Perhaps the most important function of these roots, etc., as indeed of most of our common vegetables and fruits, is to supply the body with mineral salts which are needed for the building and repair of tissue, for the proper carrying out of the physiological functions, and particularly, to insure the alkalinity of the tissues and fluids.

Not many experiments have been made to test the digestibility of this group of vegetables. What definite technical information there is indicates that they are much like other vegetables and fruits in this respect, being neither more nor less well assimilated than they are. Thus it has been found in the case of beets that 72 per cent of the protein, 97 per cent of the carbohydrates, and 90 per cent of the total energy were utilized by the body.

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[1] U. S. Dept. Agr., Office Expt. Stas. Buls. 185 (1907); 227 (1910). Chemistry of Food and Nutrition. By H. C. Sherman. New York, 1911. Food Products. By H. C. Sherman. New York, 1914.

The ways in which these and other vegetables may be prepared for the table are very numerous and have been discussed in an earlier bulletin of the department.[1]

The various vegetables included in the table of composition have each some special characteristics which merit discussion, so the more important will be taken up separately.

BEETS.

Although the greater part of the total crop of beets is used for the production of sugar or for the feeding of farm animals, beets are used in such large quantities as a human food that they rank as one of the most common table vegetables. White or yellow table beets are occasionally seen, but the red ones are the most usual. The flavor is more delicate in the summer varieties than in the later maturing sorts. Each year the southern-grown beets are becoming more common in our winter market and are superseding the large, fully matured roots which were formerly so often stored as winter vegetables and which, late in the season, often develop a rather bitter and unpleasant flavor. It is sometimes said that beets are more nutritious than turnips, carrots, etc., but a comparison of the values for average composition given in the table (p. 3) does not substantiate this statement, all these vegetables being very much alike as regards the proportion of nutritive material present.

Cane sugar constitutes a considerable portion of the total carbohydrates of beets, as high as 10 per cent or more having been often reported. Some reducing sugar is also present. In the varieties of beets grown for sugar making the percentage of cane sugar is considerably higher, sometimes 20 per cent or more, though such high values are the exception. Beets are sometimes said to be very rich in cellulose, but this does not seem to be the case with American varieties whose average composition has been quoted. When beets are cooked, a part of the sugar and other soluble nutrients which they contain is extracted, but how much material is removed can not be stated, as no cooking experiments with beets have been found on record.

Beets are frequently canned at home for winter use, and the commercial canned article is a very well known product. The canned goods have practically the same chemical composition as freshly cooked beets. Some of the girls' canning clubs, which the State and county organizations and the United States Department of Agriculture are conducting in cooperation, have put up young beets with the tops left on, or have canned both beets and tops together—an excellent way of providing iron-rich greens in the winter diet, as beet tops make a very palatable potherb.

[1] U. S. Dept. Agr., Farmers' Bul. 256 (1906).

CELERIAC.

This vegetable, which is also known as turnip-rooted celery, or knob-celery, is closely related to ordinary celery, being indeed a cultured variety of the same plant grown under conditions which have developed the root rather than the stalk. In Europe it is by far the most common form, but it has never been extensively cultivated in the United States, though it is found in the larger markets. The roots are white and more or less globular in shape, closely resembling turnips in appearance. As the figures in the table on page 3 show, they have much the same general composition as the other succulent roots and tubers. Mannit, a starch-like carbohydrate, and also small amounts of asparagin, a characteristic constituent of asparagus, have been reported present in tuberous-rooted celery. This vegetable has a pronounced celery flavor, due apparently to a complex oil like that in the seed, which is rather stronger or more abundant in the raw root than in the tender celery stalks. When cooked, celeriac does not differ very greatly in taste from the ordinary stewed celery. The leaves and stalks of celeriac are used for seasoning, and particularly as soup greens.

It is often said that celery is a nerve food, but there seems to be no warrant for such a statement, and the belief is probably a survival of the time when specific virtues were attributed to almost all plants and vegetables.

CARROTS.

Carrots are grown in many varieties and vary greatly in color, size, flavor, and other characteristics, those most commonly raised for the table being of medium size, deep-yellow color, tender, and of delicate flavor. Young carrots are much more satisfactory than old ones, as the latter tend to become hard and woody, especially at the core, while not infrequently the flavor of old carrots is disagreeably strong. Some varieties are more satisfactory than others for winter use, but winter carrots are, generally speaking, more used for seasoning soups and other dishes than as a table vegetable. Improved methods of transportation, storage, etc., have moreover, made the small, tender, southern-grown carrot comparatively common as a winter vegetable. It is not difficult to can carrots for home use, as has been proved by the girls' canning clubs.

In composition carrots do not differ very materially from other similar roots, carbohydrates constituting the principal nutritive material. Sugar is an important constituent, 12 per cent or more being sometimes present, though perhaps 5 or 6 per cent would more nearly represent the average. Small amounts of pentosans have also been reported. Carrots owe their color to the presence of a yellow organic compound known as carotin, which has been extracted with the juice and used for coloring butter.

The water in which carrots have been boiled is yellow in color and has a sweet taste, plainly showing that some of the nutrients have been removed in the process of cooking. Experiments have shown that whether the water is hot or cold at the start makes less difference than in the case of potatoes, but the more water used, the greater are the amounts of food materials extracted. On the other hand, the more rapidly the carrots are boiled, the smaller is the amount extracted. This means that quick cooking in a small quantity of water is an economical procedure. Figure 3 represents in graphic form the composition of the carrot and the loss of nutrients when boiled. Much less material is lost when the carrots are cooked by steaming. The materials extracted from the carrots in cooking consist principally of sugar or similar carbohydrates. If the water in which they or other such vegetables are cooked is saved and used in soup making or in a similar way, any real loss can be avoided.

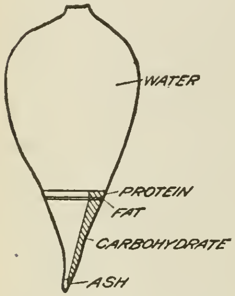

FIG. 3.—Composition and loss (shaded portion) of food material in boiling carrots.

Carrots are cooked in many ways and quite generally liked. They are also much used as a seasoning vegetable. Less commonly than was once the case, they are used with orange, lemon, or other flavoring in domestic jam making, carrot marmalade being an old favorite.

Dried or dessiccated carrots are on the market and are used to some extent where small bulk and good keeping qualities are important considerations. These goods resemble the fresh carrots in composition, except that they have been concentrated by the evaporation of water.

PARSNIPS.

Parsnips belong to the same botanical order as carrots and resemble them in form and general habit of growth. The flesh of the root, however, is paler, being white or light-cream color, and the flavor is quite distinct and very pronounced. Parsnips may be kept in the ground over winter and are especially welcome additions to the diet in early spring, when vegetables which have been stored are losing their good qualities. For some reason boiled parsnips were long considered in some regions of Europe to be the proper vegetable to serve with salt fish, but this tradition is not followed in the United States, plain boiled or fried parsnips being commonly served with roast meats of any sort. They are also used for soups, for fritters, and so on.

As regards composition, parsnips are much like the other roots and tubers, but contain rather higher quantities of cellulose, particularly in the core, which becomes stringy and woody when the roots are old. How much of the total nutritive material is lost in boiling is not definitely known, but it is commonly thought to be considerable. The amount is doubtless affected by the same conditions as were noted with carrots.

SALSIFY.

The name "salsify" is applied to three distinct vegetables; the common white salsify (*Tragopogon porrifolius*), known also on account of its flavor as oyster plant or vegetable oyster, black salsify (*Scorzonera hispanica*), the Schwarzwurzel of the German, and the so-called Spanish salsify (*Scolymus hispanicus*). The first of these is very commonly grown in the United States, and black salsify is also grown to a limited extent, while Spanish salsify is seldom cultivated. Both common salsify and black salsify closely resemble the other succulent roots used as food in general character. One distinction, however, is that the principal carbohydrate stored in black salsify is inulin rather than starch, and so this vegetable has some reputation for use in the diet of diabetics. Since the salsifies are not injured by mild frosts, they may be left in the ground until late winter or early spring.

RADISHES.

The radishes most commonly grown in the United States are the small ones with red exterior and white flesh, although white and dark-purple varieties and larger kinds are also well known. Though formerly red radishes were a typical spring or early-summer vegetable, they are now so commonly grown under glass that they are available all winter in large markets. To be at their best, radishes should be eaten before the roots are fully mature and should be very fresh. Besides losing their crispness, they become sweeter in taste if they are kept long after they are gathered, owing to the action of a ferment or enzym normally present which changes part of the radish starch to sugar. Similar enzyms are found in beets, carrots, etc., but in these vegetables the action is less marked.

As will be seen from the figures in the table (p. 3), young radishes contain even more water than turnips. (See also fig. 1, p. 5.) The characteristic pungent flavor is due to organic compounds containing sulphur, similar to the essential oil in mustard. Radishes are so succulent and tender that they are doubtless well assimilated, though, as far as can be learned, their digestibility has not been studied. It is frequently said that they are productive of digestive disturbances, but such disturbances are by no means general, and when they occur may be due to insufficient mastication—a common occurrence in the case of succulent foods.

Besides the common radish, of which the pink or red form is the best known, there are larger sorts, sometimes called turnip radish, which are white or purplish in color. These are at their best in summer, but have such good keeping qualities that they may be held over for winter use. Though common in many American markets, these larger varieties are less well known than in parts of Europe. There is also a large variety of Japanese radish which has been grown to some extent in the United States.

Though most commonly eaten raw, radishes, especially the larger sorts, are also cooked and served like creamed turnip, which they much resemble in flavor. The leaves can be used for greens, or if they are very tender can be added to salads. The young and tender seed pods of some varieties are sometimes used for pickling like capers; in fact, the Madras or rat-tail radish is grown exclusively for its pods, which are cooked and also used in pickle making.

TURNIPS.

Many varieties of turnips are grown throughout temperate climates, some of which are coarse in texture and used as food for farm animals, while others are raised as table vegetables. There is considerable variation in the color, flavor, and composition of the turnip, there being two groups commonly distinguished, one having leaves with a smooth surface and glaucous bloom and called "Swedes" or "rutabagas." Turnips are usually white-fleshed and rutabagas yellow-fleshed, though the distinction does not always hold good. In the summer the early white varieties are usually preferred in spite of the fact that they are more watery, while in winter the yellow turnips are more commonly used. Solid as the turnip roots appear, they contain on an average about 89 per cent of water, or a trifle more than is found in whole milk. The total amount of nitrogenous substance is small, and only about 20 per cent of the total present is in the form of true protein. Carbohydrates are the principal nutritive material, glucose, cane sugar, pectose, pentosans, and crude fiber being the characteristic forms. The flavor of the turnip, like that of its relatives, the cabbage and the radish, is due principally to compounds of sulphur, which are so volatile that when turnips are fed to cows these compounds pass through the body tissues and into the milk and give it an unmistakable flavor. In cooking, these pungent substances are broken down to some extent and pass off into the air.

KOHL-RABI.

Kohl-rabi, or turnip-rooted cabbage, represents a curious variety of the turnip and cabbage family in which the reserve material of the plant is stored in an above-ground tuberlike enlargement of the stem just above the seed leaves or cotyledons. Although, strictly speaking, it does not belong to the roots and tubers, it is so similar to them in composition, in methods of cookery, and in uses that it has been included in this discussion. Kohl-rabi is considered best in the early summer, when it is still young and tender, but it is commonly found on the market until late fall. In flavor it is more delicate than either the turnip or cabbage, though it resembles them more nearly in this respect than it does other common vegetables. Like turnip, it can be diced, cooked, and served with butter or cream sauce. It can be cooked with other vegetables with salt meat in a "boiled dinner," or sliced and used in soup as a seasoning vegetable. Kohl-rabi leaves if not too tough are excellent when cooked as greens, and may be served as a border around the kohl-rabi or as a separate dish.

ONIONS, GARLIC, AND SIMILAR VEGETABLES.

These plants are prized for use alone and for the flavor they impart to other foods, so they can be classed both with succulent roots and with those used as condiments. Onions are so frequently eaten as a vegetable that it seems logical to discuss them primarily in comparison with such materials as beets, radishes, etc.

All the members of the onion family are characterized by very strong flavor and odor, due to the presence of allyl sulphid, an oil-like organic compound of sulphur. Different varieties vary somewhat in flavor and composition, and the flavor is usually more pronounced in the bulbs and roots than in the leaves or other parts, and in old than in young plants. The flavor-yielding material is very volatile and is broken down by heat to some extent. Consequently, the cooked vegetable has a milder flavor than the raw.

In the United States the common onion in its many varieties is the best known and most used member of the onion family. The bulbs vary in size from the tiny pearl onions used for pickle making to the very large Spanish onions weighing a pound or more each. The range in color is also wide and varies from silver white, cream white, green, or yellow to red or reddish purple. The total crop produced is very large, and quantities are also imported from southern Europe, Bermuda, and the West Indies. As with most vegetables, the young and somewhat immature onions are preferred to the fully matured bulbs, though the latter have the best keeping qualities. In general, white varieties are milder in flavor than the red or yellow sorts and are generally preferred as table vegetables. If they are to be kept through the winter, onions should be taken from the ground as soon as the stalks begin to wither and cured or dried in the air for about 10 days. If moist when stored they will not keep well.

The proportion of water and nutrients in onions varies greatly, not only with the variety but with the stage of growth and the method of storing them. Roughly speaking, the chemical composition is very similar to that of the succulent roots included in the table (p. 3). Onions contain, however, rather larger quantities of cellulose, particularly in the outer layers, which is a reason why these are usually removed before cooking. The waste in peeling and trimming onions (fig. 4) for the table may be as high as 50 per cent, but 20 or 30 per cent is perhaps a fair average. They are commonly conceded to be wholesome and have been prized since the earliest times as a valuable addition to the diet. The characteristic sulphur compound which they contain is believed to stimulate the flow of digestive juices, and this and other constitutents have a desirable effect in overcoming a tendency to constipation. As onions contain no appreciable amount of starch and little sugar, they are commonly allowed to invalids from whose diet starchy foods are excluded.

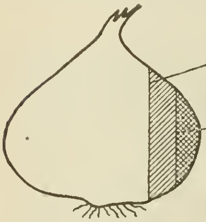

Fig. 4.—Loss in peeling and trimming onions.

Garlic is a member of the onion tribe which produces a collection of small bulbs called "cloves" in the place of one large bulb. Some of the mild varieties grown in the Mediterranean region are eaten as vegetables, but in this country garlic is used mainly as a flavoring. Even so, its use is uncommon except among persons of foreign birth or food habits, and this seems unfortunate, as, rightly used, garlic may add to the palatability of salads, meats, and other dishes.

Shallot, cibol, etc., are varieties of the onion family yielding bulbs which are much esteemed for their flavor in Europe, though they are not common in the United States. Leeks and chives, two other sorts, develop almost no bulbs and are grown for their leaves, leeks being used as a green vegetable or potherb and chives mainly for seasoning. Although most families in the United States are familiar with onions, they do not generally know the similar vegetables. However, professional cooks consider that the other members of the group are well worth using and that some of them are almost indispensable for seasoning purposes.

As is the case with so many of the succulent root vegetables, the green tops of onions and leeks are excellent cooked as greens.

ROOT VEGETABLES LESS COMMONLY KNOWN.

In other parts of the world, or in other times, many succulent roots have been used as food which, though known in the United States and grown to some extent, are seldom seen on our tables. Some of them might well be more commonly known, while others are sufficiently interesting for one reason or another to be worth at least brief mention here.

Chervil is a plant, two forms of which are common in Europe. One of them (*Anthriscus cerefolium*) is sometimes called sweet cicely and is cultivated mainly for its leaves, which are used as a salad. The other, known as tuberous or turnip-rooted chervil (*Chærophyllum bulbosum*), is a true root vegetable. The roots are about the size and shape of small carrots and are gray or blackish on the outside, with yellow-white flesh and with a distinctive flavor. They are used in much the same way as young carrots. Seedsmen offer the seeds, but they have never been common in the United States.

The chufa, or nut grass, or earth almond, for it is known by all of these names, is the small tuberous root of a sedgelike plant which has a flavor suggesting nuts. A native of southern Europe, it is now cultivated in many countries. Though used as a food in a limited way, it is chiefly important as a feeding stuff. The chufa nuts are well known to children in the Southern States.

The bulbs of various lilies are eaten in the Orient and are on sale in Chinese quarters and served in Chinese restaurants in many American cities. The American Indians ate and to a small extent still use lily bulbs or corms, both roasted and raw, including the Indian cucumber (*Medeola virginica*), a relative of the trillium, the roots of water lilies, and many other wild roots, few of which have been taken over into the diet of other peoples.

ROOTS USED AS CONDIMENTS.

Several roots have pronounced aromatic qualities which give them a condimental value quite independent of the nutritive material which they contain. In addition to increasing the flavor of foods, it seems possible that such condiments may stimulate the flow of digestive juices as well as please the palate. Horse-radish and ginger are the most common condimental roots, though chicory, so commonly considered in Europe a palatable addition to coffee, may also be mentioned, as well as licorice root and calamus, or sweet flag, and wild ginger, or snakeroot.

Horse-radish is a moisture-loving plant of the mustard family which is cultivated throughout north-temperate countries and is very frequently found wild in the United States, as it long ago escaped from cultivation. The root is long, rather slender, and has a sharp, peppery flavor, owing to the presence of an essential oil which much resembles in general character that in the radish and other members of the mustard family. As regards composition, horse-radish contains on an average 86.4 per cent water, 1.4 per cent protein, 0.2 per cent fat, 10.5 per cent total carbohydrates, and 1.5

per cent ash, and has a fuel value of 225 calories per pound. Its water content is so high that it may be grouped with the succulent roots in spite of the fact that starch constitutes the principal carbohydrate present. As might be expected from the stringy character of the roots, the percentage of crude fiber is rather high. Though certain varieties of horse-radish are sometimes cooked as a vegetable and it is used for seasoning pickles, for making sauces,[1] to serve with meat, etc., its most common use in this country is as a condiment, when it is mixed with vinegar. It is popularly supposed that the vinegar softens the crude fiber to some extent and makes it more digestible.

Ginger, the underground rootstock of the ginger plant (*Zingiber officinale*), is perhaps most frequently used dry as a spice, though the fresh root or green ginger is common in autumn, being used in pickle making, preserving, and in other ways. Large quantities of ginger root are preserved in rich sugar sirup, "Canton ginger" in its round stone jars being an old-fashioned confection which is still much prized. The crystallized or candied ginger is even more common; it, like preserved ginger, is frequently served as a sweetmeat. It is also used in making desserts of various sorts[2] and is generally used like candied fruits. While the nutritive value of preserved or crystallized ginger depends, of course, quite largely on the added sugar, the fresh root contains some nutritive material, the average composition being 85.6 per cent water, 1 per cent protein, 0.6 per cent fat, 11.4 per cent sugar, starch, etc., 1 per cent crude fiber, and 1.4 per cent ash, and has a fuel value of 240 calories per pound. Of the total fat or ether extract, about half consists of the ethereal oil which, together with a pungent, nonvolatile constituent called gingerol, gives to ginger its characteristic flavor. The young and tender ends of the branching root, or rhizome, called ginger buds, are the most delicate portion as regards both texture and flavor.

Calamus, or flagroot, is found wild in Europe, as well as in the United States, and has long been known for its pungent and aromatic flavor. The root is most often gathered, though the young blossom portion is also eaten and has a specially mild flavor. Flagroot was used for a seasoning in earlier times in England and in the United States also, where it is still used to a limited extent like candied citron to flavor stewed fruit and so on, though its use at the present time is very largely limited to the candied flagroot which housekeepers often make at home and which is also a commercial product.

[1] U. S. Dept. Agr., Farmers' Bul. 391 (1910), p. 27. [Recipe for making horse-radish sauce.]

[2] U. S. Dept. Agr., Yearbook 1912, pp. 505–552. Raisins, Figs, and Other Dried Fruits and Their Use.

Wild ginger (*Asarum canadense*), or the snakeroot of our northern woods, may also be mentioned. The spicy, aromatic root of this plant was gathered quite commonly in earlier times and dried, being used like many other wild plants in domestic medicine. Its use as a condiment was also common, a bit of the dried root being carried about and nibbled at odd times in the same way as calamus and dried orris root. In pioneer cookery it occasionally took the place of some more common spice, and does now, the fresh root being used to some extent like true ginger in pickle making. It also can be candied.

Laboratory tests have shown that both flagroot and wild ginger root used in cookery in small quantities in place of other spices give a distinctive flavor which many would consider pleasant.

Another native American root—sassafras—which has some importance for condimental purposes, may be mentioned here. The bark of the root yields a flavoring extract more used in confectionery making than in the home. However, it is interesting to know that tea made from this root, which was once so common a beverage under the name of "saloop," is still used to some extent in parts of the United States, both in the home and commercially.

SUMMARY.

The plants which store their reserve material in underground roots, tubers, and bulbs have, in many instances, come to be regarded by man as among the most important foodstuffs. Cultivation has to a great extent modified the size, structure, flavor, and appearance of the parts which are eaten, and the garden varieties are as a rule superior to the wild in these respects and show important modifications in the season of growth and in other ways. As a class the edible roots, tubers, and bulbs may be divided into the following groups: (1) Starch-yielding vegetables, as potatoes, sweet potatoes, dasheens, etc.; (2) succulent roots, as beets, carrots, and parsnips; and (3) condimental or flavoring roots, as horse-radish and ginger.

The edible roots, tubers, and bulbs have a high water content and are valued as additions to the diet for their appetizing, succulent qualities and the bulk which they give, as well as for the nutritive material which they supply. Starch is the material most commonly stored in the underground receptacles, though it is replaced in some plants by closely related bodies such as inulin, mannin, etc., by sugars of different sorts, pectoses, or other carbohydrates. The proportion of nitrogenous material in such foodstuffs is small, and true albumin seldom constitutes more than a third of the total protein. The proportion of fat is also small, being composed in some cases very largely of wax-like bodies found in the skin, or of coloring matter; and in other cases, of volatile oils and similar substances, which give the plants their characteristic flavor and odor. Mineral matter is an important constituent of these vegetable foods, the proportion, though small, being about the same as is found in many other common articles of diet. Sodium, potassium, iron, sulphur, and phosphorus compounds are the common mineral constituents. As the mineral matters exist in combination with organic acids and other bodies, they contribute materially to the flavor of the tubers, roots, etc.

Beets, carrots, parsnips, salsify, turnips, and onions are the most common of the so-called succulent root crops used as food. They differ from starch-yielding vegetables like potatoes mainly in containing a larger proportion of water, 85 to 90 per cent on an average, and consequently a smaller proportion of nutritive material. Furthermore, it is generally true that starch is not the characteristic carbohydrate of these vegetables, its place being taken by sugars of different sorts, pectose bodies, and other similar carbohydrates, while the percentage of crude fiber is also rather higher than in the edible starch-yielding roots and tubers. Many of the vegetables included in this group are characterized by marked flavors and odors due to the presence of volatile organic sulphur compounds in their juices. In the members of the onion tribe these are especially strong, and some varieties are used almost exclusively as flavoring materials, while other and milder sorts are also used in large quantities as table vegetables.

Though not very nutritious in proportion to their bulk, root crops as a class offer some advantages over most other vegetable foods. They are so easily grown and so productive that under ordinary conditions they sell at prices within the reach of all. Many of them may be kept over winter in such good condition that they are practically never out of season, or are in season when other vegetables are scarce. The carbohydrates, the principal nutritive material present, are in forms which are readily and well assimilated. The characteristic flavor which some of these vegetables possess is a decided advantage, as it makes the vegetables palatable and adds to the variety of the diet. Succulent vegetables of all sorts contribute bulk to the diet and so are valuable from the standpoint of hygiene, because within limits bulkiness is a favorable condition for normal digestion and also of importance in overcoming a tendency to constipation. They are among the important sources of necessary mineral matters in the ordinary diet. Since the body performs its functions best if its tissues and fluids are either neutral or slightly alkaline, and since vegetables tend to produce that effect, they have a special value as regulators of the body processes.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 504

OFFICE OF THE SECRETARY
Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief

Washington, D. C. PROFESSIONAL PAPER May 23, 1917

THE THEORY OF CORRELATION AS APPLIED TO FARM-SURVEY DATA ON FATTENING BABY BEEF.

By H. R. Tolley, *Scientific Assistant.*

CONTENTS.

INTRODUCTION.

This paper sets forth the results of an experiment in applying the theory of correlation, hitherto used chiefly in the analysis of biological, sociological, psychological, and meteorological statistics,[1] to the study of some of the data of the Office of Farm Management.

The material for the investigation was obtained from 67 records taken during the years 1914 and 1915 from farmers of the corn belt who were fattening baby beef for market.[2] The factors considered were: The profit or loss per head, the weight, value per hundredweight, value of feed consumed per head, cost at weaning time, and date of sale (see Table I). Coefficients of correlation were computed for every pair of these factors and used as a measure of the relationship existing between them.

THEORY OF CORRELATION.

The writer will not attempt a detailed explanation of the theory of correlation but will discuss briefly the meaning of coefficients of correlation and the method by which they are obtained.

[1] Yule, G. U.: "Introduction to the Theory of Statistics," 1912. Yule, G. U.: "On the Theory of Correlation," Jour. Roy. Stat. Soc., 1897, p. 812. Davenport, C. B.: "Statistical Methods, With Special Reference to Biological Variation," 1914. Hooker, R. H.: "The Correlation of the Weather and the Crops," Jour. Roy. Stat. Soc., 1907, p. 1. Smith, J. W.; "Effect of Weather on Yield of Corn," Monthly Weather Review, vol. 42, p. 72; and "Effect of Weather on Yield of Potatoes," ibid., vol. 43, p. 232. Brown, Wm.: "Essentials of Mental Measurement," 1911.

[2] For detailed account of the methods by which these data were obtained and the costs computed, see Report 111, Office of the Secretary, 1916.

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TABLE I.—*Data on cost of producing baby beef.*

Farm No.	Profit per head.[1]	Weight per head.	Value per hundred-weight.	Total value of feed per head.	Cost per head at weaning time.	Date of sale (months).[2]
		Pounds.				
1	+$12.07	785	$8.35	$31.49	$23.12	8.7
2	− 22.98	750	7.75	29.62	46.33	6.3
3	+ 2.79	690	7.20	20.90	30.94	2.6
4	+ 6.07	820	8.00	30.00	30.02	6.4
5	− 14.05	852	7.52	31.88	44.15	12.7
6	− 9.93	1,000	9.75	37.47	64.34	12.3
7	+ 13.68	825	8.50	32.68	25.76	8.8
8	+ 15.15	825	8.50	23.04	32.64	8.8
9	+ 27.42	800	9.50	31.06	18.01	8.5
10	− 8.92	875	9.75	59.10	33.92	8.8
11	− 19.09	922	10.14	70.52	40.20	9.9
12	+ 18.75	810	9.30	30.25	28.08	9.0
13	− 7.07	1,080	9.75	71.01	38.62	8.9
14	+ 13.53	1,048	10.11	47.43	39.83	10.0
15	+ 38.15	1,012	10.35	49.47	20.47	10.9
16	+ 9.83	1,000	9.75	40.56	42.89	10.0
17	+ 19.05	807	9.70	33.58	28.43	4.3
18	− 5.73	915	9.10	38.41	51.36	8.0
19	− 2.39	910	9.15	45.48	42.17	5.0
20	+ 10.93	890	9.70	48.95	25.86	8.2
21	+ 9.67	876	9.40	23.91	43.98	8.7
22	− 3.65	988	8.75	43.95	38.52	12.2
23	+ 49.37	1,050	9.75	27.08	27.74	10.3
24	− 7.28	798	8.25	42.84	30.09	8.0
25	− 43.00	675	8.00	44.71	50.80	6.6
26	+ 5.65	689	7.75	23.39	24.61	5.5
27	+ 0.59	860	10.00	49.74	35.85	7.5
28	− 7.71	746	8.00	26.53	40.30	6.7
29	− 2.78	850	8.90	33.35	43.46	6.5
30	− 1.36	890	7.30	20.33	49.80	3.5
31	+ 6.76	859	8.15	27.73	30.89	4.0
32	+ 7.91	765	8.10	21.02	30.83	6.0
33	+ 18.07	744	9.48	34.95	19.51	7.2
34	+ 1.33	700	9.00	31.61	28.25	5.0
35	− 32.63	740	9.25	45.72	49.76	5.9
36	+ 12.97	800	9.00	31.00	26.57	6.5
37	+ 11.15	800	7.30	17.96	27.11	2.7
38	− 43.71	740	8.50	20.12	85.66	5.0
39	+ 18.15	700	7.75	9.38	24.78	3.8
40	− 9.86	785	8.25	33.70	38.73	8.8
41	+ 2.18	656	8.14	21.90	30.09	4.9
42	+ 23.99	925	8.60	26.75	28.55	5.9
43	− 22.97	766	8.40	54.46	35.09	6.9
44	− 12.73	750	8.50	18.02	54.33	7.0
45	+ 11.80	805	8.00	20.76	34.62	5.0
46	− 22.90	924	9.85	57.59	56.63	8.0
47	+ 0.27	800	9.25	48.53	28.97	7.6
48	+ 5.37	800	8.25	29.79	29.03	5.7
49	+ 5.33	862	10.20	49.77	30.90	10.7
50	+ 2.82	800	9.00	24.81	42.86	7.0
51	+ 16.68	840	10.00	45.54	19.54	8.0
52	− 7.07	840	9.25	41.09	37.53	7.7
53	− 3.09	650	7.50	12.28	41.66	3.0
54	− 24.04	775	8.40	39.86	47.90	6.0
55	− 10.45	741	8.50	29.04	45.68	6.0
56	+ 2.83	768	7.20	24.53	29.62	6.0
57	− 0.09	1,060	8.30	47.10	45.41	3.0
58	+ 3.88	900	8.95	37.02	42.27	6.0
59	− 6.42	793	9.60	56.46	27.69	8.5
60	− 8.37	855	8.55	42.40	40.51	5.5
61	− 27.61	850	8.05	43.83	51.29	6.0
62	+ 1.64	915	8.55	34.41	39.39	6.2
63	− 0.18	811	8.60	37.13	32.90	8.9
64	− 1.00	775	8.20	18.30	43.72	5.0
65	+ 8.00	742	8.25	17.39	34.85	6.9
66	+ 5.55	827	8.50	22.30	42.05	7.3
67	+ 21.73	950	9.50	33.64	32.09	12.0
Average..	+ 0.78	834	8.76	35.02	37.01	7.2

[1] A plus sign before the quantity in this column indicates a gain; a minus sign, a loss.
[2] In order to facilitate computation, the dates have been expressed in months and decimals of a month after Jan. 1; i. e., 8.7 indicates Aug. 20, 21, or 22; 6.3 indicates June 8, 9, or 10, etc.

If, in two series of associated variables, as, say, the profit per head and the weight per head in the data under consideration, there is a tendency for a high value of the first to be associated with a high value of the second, the variables are said to be correlated, and the correlation is positive; while if a high value of the first is associated with a low value of the second, and vice versa, the correlation is said to be negative, and the best measure yet devised of the amount of the correlation is the so-called coefficient of correlation. In Table II is shown the calculation of the coefficient of correlation between profit and weight per head.

The method is as follows:

1. Find the average value for each of the variables. Here the average profit per head is \$0.78, and the average weight 834 pounds.
2. Calculate the departure of the individual values from the average. In the case of record No. 1, the departure of the profit from the average is +\$11.29, and of the weight, −49 pounds.
3. Find the square root of the average of the squares of these departures. This is the so-called "standard deviation," and is a measure of dispersion or the amount of variability of each variable.
4. Find the algebraic sum of the products of each pair of individual departures, i. e., for each record, multiply the departure of the profit from the average by the departure of the weight from the average, and prefix the proper sign; then find the difference between the sum of all the plus products and the sum of all the minus products.
5. Divide this result by the number of records and the standard deviation of each of the variables in turn, prefix the proper sign, and the figure obtained is the coefficient of correlation between the two factors under consideration.

If there are approximately the same number of positive and negative products and they are of the same size, it will be evident that there is no correlation, and this will be shown by the fact that the coefficient of correlation will be zero, or nearly so. If high values of the first variable are associated with high values of the second, and low values of the first with low values of the second, most of the products will be plus, and the greater their sum the closer will be the correlation and the larger will be the coefficient obtained. If a value of one variable below the average is generally associated with a value of the other above the average, the correlation will evidently be negative, and this will be shown by the fact that the sum of the products will be negative, the degree of the correlation and the size of the coefficient depending upon the size of this sum.

Expressed algebraically, the coefficient of correlation,

$$r=\frac{\Sigma xy}{n\sigma_x\sigma_y}; \tag{I}$$

where Σxy is the sum of the products above mentioned, n is the number of pairs of variables (the same as the number of records); σ_x

TABLE II.—*Calculation of coefficient of correlation between profit and weight per head.*

Farm No.	Profit per head.[1]	x.	x^2.	Weight per head.	y.	y^2.	xy.
				Pounds.			
1	+$12.07	+11.29	+127.69	785	− 49	+2,401	− 553.7
2	− 22.98	−23.76	566.44	750	− 84	7,056	+ 1,999.2
3	+ 2.79	+ 2.01	4.00	690	−144	20,736	− 288.0
4	+ 6.07	+ 5.29	28.09	820	− 14	196	− 74.2
5	− 14.05	−14.83	219.04	852	+ 18	324	− 266.4
6	− 9.93	−10.71	114.49	1,000	+166	27,556	− 1,776.2
7	+ 13.68	+12.90	166.41	825	− 9	81	− 116.1
8	+ 15.15	+14.37	207.36	825	− 9	81	− 129.6
9	+ 27.42	+26.64	707.56	800	− 34	1,156	− 904.4
10	− 8.92	− 9.70	94.09	875	+ 41	1,681	− 397.7
11	− 19.09	−19.87	396.01	922	+ 88	7,724	− 1,751.2
12	+ 18.75	+17.97	324.00	810	− 24	576	− 432.0
13	− 7.07	− 7.85	62.41	1,080	+246	60,516	− 1,943.4
14	+ 13.53	+12.75	163.84	1,048	+214	45,796	+ 2,739.2
15	+ 38.15	+37.37	1,398.76	1,012	+178	31,684	+ 6,657.2
16	+ 9.83	+ 9.05	81.00	1,000	+166	27,556	+ 1,494.0
17	+ 19.05	+18.27	334.89	807	− 27	729	− 494.1
18	− 5.73	− 6.51	42.25	915	+ 81	6,561	− 526.5
19	− 2.39	− 3.17	10.24	910	+ 76	5,776	− 243.2
20	+ 10.93	+10.15	104.04	890	+ 56	3,136	+ 571.2
21	+ 9.67	+ 8.89	79.21	876	+ 42	1,764	+ 373.8
22	− 3.65	− 4.43	19.36	988	+154	23,716	− 677.6
23	+ 49.37	+48.59	2,361.96	1,050	+216	46,656	+10,497.6
24	− 7.28	− 8.06	65.61	798	− 36	1,296	+ 291.6
25	− 43.00	−43.78	1,918.44	675	−159	25,281	+ 6,964.2
26	+ 5.65	+ 4.87	24.01	689	−145	21,025	− 710.5
27	+ 0.59	− 0.19	.04	860	+ 26	676	− 5.2
28	− 7.71	− 8.49	72.25	746	− 88	7,744	+ 748.0
29	− 2.78	− 3.56	12.96	850	+ 16	256	− 57.6
30	− 1.36	− 2.14	4.41	890	+ 56	3,136	− 117.6
31	+ 6.76	+ 5.98	36.00	859	+ 25	625	+ 150.0
32	+ 7.91	+ 7.13	50.41	765	− 69	4,761	− 489.9
33	+ 18.07	+17.29	299.29	744	− 90	8,100	− 1,557.0
34	+ 1.33	+ 0.55	.36	700	−134	17,956	− 80.4
35	− 32.63	−33.41	1,115.56	740	− 94	8,836	+ 3,139.6
36	+ 12.97	+12.19	148.84	800	− 34	1,156	− 414.8
37	+ 11.15	+10.37	108.16	800	− 34	1,156	− 353.6
38	− 43.71	−44.49	1,980.25	740	− 94	8.836	+ 4,183.0
39	+ 18.15	+17.37	302.76	700.	−134	17,956	− 2,331.6
40	− 9.86	−10.64	112.36	785	− 49	2,401	+ 519.4
41	+ 2.18	+ 1.40	1.96	656	−178	31,684	− 249.2
42	+ 23.99	+23.21	556.96	925	+ 91	8,281	+ 2,111.2
43	− 22.97	−23.75	566.44	766	− 68	4,624	+ 1,618.4
44	− 12.73	−13.63	184.96	750	− 84	7,056	+ 1,142.4
45	+ 11.80	+11.02	121.00	805	− 29	841	− 319.0
46	− 22.90	−23.68	561.69	924	+ 90	8,100	− 2,133.0
47	+ 0.27	− 0.51	.25	800	− 34	1,156	+ 17.0
48	+ 5.37	+ 4.59	21.16	800	− 34	1,156	− 156.4
49	+ 5.33	+ 4.55	21.16	862	+ 28	784	+ 128.8
50	+ 2.82	+ 2.04	4.00	800	− 34	1,156	− 68.0
51	+ 16.68	+15.90	252.81	840	+ 6	36	+ 95.4
52	− 7.07	− 7.85	60.84	840	+ 6	36	− 46.8
53	− 3.09	− 3.87	15.21	650	−184	33,856	+ 717.6
54	− 24.04	−24.82	615.04	775	− 59	3,481	+ 1,463.2
55	− 10.45	−11.23	125.44	741	− 93	8,649	+ 1,041.6
56	+ 2.83	+ 2.05	4.00	768	− 66	4,356	− 132.0
57	− 0.09	− 0.87	.81	1,060	+226	51,076	− 203.4
58	+ 3.88	+ 3.10	9.61	900	+ 66	4,356	+ 204.6
59	− 6.42	− 7.20	51.84	793	− 41	1,681	+ 295.2
60	− 8.37	− 9.15	84.64	855	+ 21	441	− 193.2
61	− 27.61	−28.36	806.56	850	+ 16	256	− 454.4
62	+ 1.64	+ 0.86	.81	915	+ 81	6,561	+ 72.9
63	− 0.18	− 0.96	1.00	811	− 23	529	+ 23.0
64	− 1.00	− 1.78	3.24	775	− 59	3,481	+ 106.2
65	+ 8.00	+ 7.22	51.84	742	− 92	8,464	− 662.4
66	+ 5.55	+ 4.77	23.04	827	− 7	49	− 33.6
67	+ 21.73	+20.95	441.00	950	+116	13,456	+ 2,436.0
	Average, +0.78		18,452.16 σ_x=$16.60	Average, 834		660,257 σ_y=99 lbs.	+30,457.6

$$r=\frac{\Sigma xy}{n\sigma_x\sigma_y}=\frac{+30457.6}{(67)(16.60)(99)}=+0.277$$

$$E_r=\pm.6745\,\frac{1-r^2}{\sqrt{n}}=\pm.076$$

[1] A plus sign before the quantity in this column indicates a profit, a minus sign a loss. The quantities in the column headed x are given to two places of decimals, but it was found that the use of one decimal place would give the quantities in the x^2 and xy columns with sufficient accuracy, and the computations were made accordingly. Thus, for farm No. 1, $(11.3)^2=127.69$, and $(+11.3)\ )-49)=-553.7$.

is the standard deviation of the first variable; and σ_y the standard deviation of the second. The value of "r" will always be between +1 and −1, +1 indicating perfect positive correlation, and −1 perfect negative correlation; and to be significant, the value should be appreciably greater than its probable error,

$$E_r = \frac{\pm .6745(1-r^2)}{\sqrt{n}}. \qquad \text{(II)}$$

In the example, $r=+.277$, and its probable error is $\pm.076$, so there was a tendency for the heavier calves to return a greater profit, but the correlation is by no means perfect.

PARTIAL CORRELATION.

A study in which many factors are concerned is not complete until it is determined whether or not an apparent correlation, measured in the manner explained above, is due to the fact that each of the two variables (or factors) under consideration is correlated with another or even several other variables. For instance, in the data under consideration there is apparently a high correlation between the weight of the calves and the value per hundredweight received for them ($r=+.56$), and the question now arises if heavier calves really do demand a higher price on the market. This correlation might be due entirely or in part to the fact that the heavier calves in the records obtained were sold at a later date, and that the price of cattle in general was higher later in the season; that is, the correlation exhibited here might be due to the fact that both weight and price are correlated with date of sale.

In a problem of this type, where it is necessary to consider simultaneously the relation between three variables and to determine the correlation between any two, a coefficient of net or partial correlation[1] can be determined by the formula—

$$r_{ab.c} = \frac{r_{ab} - r_{ac} \cdot r_{bc}}{\sqrt{(1-r^2_{ac})(1-r^2_{bc})}} \qquad \text{(III)}$$

Calling the three variables a, b, and c, the terms of the formula are: $r_{ab \cdot c}$ is the coefficient of net correlation between a and b, when the effect of c is considered; r_{ab} is the ordinary coefficient of gross correlation between a and b and is obtained as explained above; r_{ac} and r_{bc} are the coefficients of gross correlation between a and c and b and c, respectively. Continuing with the example above, let us endeavor to determine the degree of correlation between weight and value per hundredweight, after taking into account any effect that date of sale might have had. In other words, we seek an answer to the question:

[1] Yule, G. U.: "Introduction to the Theory of Statistics," p. 229 et seq.

What would have been the coefficient of correlation between weight and price if all the calves had been sold on the same date? Calling the weight w, the value per hundredweight v, and the date of sale d, the gross correlation coefficients are:[1] $r_{wv}=+.56$; $r_{vd}=+.61$; $r_{wd}=+.60$. Applying the formula (III), we have:

$$r_{wv.d}=\frac{+.56-(+.61)(+.60)}{\sqrt{(1-.61^2)(1-60^2)}}=+.31$$

This value, +.31, is appreciably smaller than the value, +.56, of the gross coefficient, showing that the apparent correlation between weight and price is partly, but not entirely, due to their mutual correlation with the date of sale.

This theory can be applied to the case of several variables by a simple extension of the formula.[2]

In the general case for six variables, the total number considered in this paper—

$$r_{ab.cdef}=\frac{r_{ab.cde}-r_{af.cde}\cdot r_{bf.cde}}{\sqrt{(1-r^2_{af.cde})\,(1-r^2_{bf.cde})}}. \qquad \text{(IV)}$$

$r_{ab\cdot cdef}$ is the net coefficient of correlation between a and b, when the four factors, c, d, e, and f, are taken into account: $r_{ab\cdot cde}$, $r_{af\cdot cde}$, and $r_{bf\cdot cde}$ are the coefficients of correlation between the two variables before the period in each case when c, d, and e are taken into account.

COMPUTATION OF THE COEFFICIENTS.

The first step in the arithmetic was the computation of the gross correlation coefficients. As stated above, the variables or factors considered were: (1) The profit or loss per head; (2) weight; (3) value per hundredweight; (4) total value of feed consumed per head; (5) cost per head at weaning time; and (6) date of sale. These six variables, if taken two at a time, can be combined in 15 different ways. The first calculation was to find the coefficients of correlation between these 15 different pairs. In Table III these are the first values given. The effect of every other factor on these gross coefficients was then eliminated by successive applications of formulæ III and IV. As an example, take profit and weight, the first pair of variables correlated. The gross coefficient was first corrected for the effect of value per hundredweight, value of feed consumed, initial cost, and date of sale, in turn. Then the effect of these four factors was considered, taking them two at a time. That is, the correlation was determined when both the value per hundredweight and the cost of feed were taken into consideration at the same time. When the effect of all these factors, taking them

[1] See Table III: Correlation coefficients.

[2] Yule, G. U.: "Introduction to the Theory of Statistics," p. 229 et seq.

TABLE III.—*Correlation coefficients.*

Profit (*p*) and Weight (*w*).		Profit (*p*) and Value per hundredweight (*v*).		Profit (*p*) and Value of feed (*f*).		Profit (*p*) and Cost at weaning time (*c*).		Profit (*p*) and Date of Sale (*d*).	
r_{pw}	+0.28	r_{pv}	+0.23	r_{pf}	−0.27	r_{pc}	−0.73	r_{pd}	+0.14
$r_{pw\cdot v}$	+.18	$r_{pv\cdot w}$	+.10	$r_{pf\cdot w}$	−.50	$r_{pc\cdot w}$	−.78	$r_{pd\cdot w}$	−.03
$r_{pw\cdot f}$	+.50	$r_{pv\cdot f}$	+.56	$r_{pf\cdot v}$	−.58	$r_{pc\cdot v}$	−.73	$r_{pd\cdot v}$	.00
$r_{pw\cdot c}$	+.48	$r_{pv\cdot c}$	+.25	$r_{pf\cdot c}$	−.38	$r_{pc\cdot f}$	−.75	$r_{pd\cdot f}$	+.29
$r_{pw\cdot d}$	+.24	$r_{pv\cdot d}$	+.19	$r_{pf\cdot d}$	−.37	$r_{pc\cdot d}$	−.73	$r_{pd\cdot c}$	+.16
$r_{pw\cdot vf}$	+.39	$r_{pv\cdot wf}$	+.48	$r_{pf\cdot wv}$	−.64	$r_{pc\cdot wv}$	−.78	$r_{pd\cdot wv}$	−.08
$r_{pw\cdot vc}$	+.43	$r_{pv\cdot wc}$	−.04	$r_{pf\cdot wc}$	−.83	$r_{pc\cdot wf}$	−.92	$r_{pd\cdot wf}$	+.06
$r_{pw\cdot vd}$	+.20	$r_{pv\cdot wd}$	+.12	$r_{pf\cdot wd}$	−.50	$r_{pc\cdot wd}$	−.79	$r_{pd\cdot wc}$	−.18
$r_{pw\cdot fc}$	+.85	$r_{pv\cdot fc}$	+.71	$r_{pf\cdot vc}$	−.74	$r_{pc\cdot vf}$	−.83	$r_{pd\cdot vf}$	+.02
$r_{pw\cdot fd}$	+.43	$r_{pv\cdot fd}$	+.50	$r_{pf\cdot vd}$	−.58	$r_{pc\cdot vd}$	−.73	$r_{pd\cdot vc}$	+.02
$r_{pw\cdot cd}$	+.49	$r_{pv\cdot cd}$	+.18	$r_{pf\cdot cd}$	−.50	$r_{pc\cdot fd}$	−.77	$r_{pd\cdot fc}$	+.38
$r_{pw\cdot vfc}$	+.91	$r_{pv\cdot wfc}$	+.83	$r_{pf\cdot wvc}$	−.95	$r_{pc\cdot wvf}$	−.97	$r_{pd\cdot wvf}$	−.15
$r_{pw\cdot vfd}$	+.42	$r_{pv\cdot wfd}$	+.49	$r_{pf\cdot wvd}$	−.65	$r_{pc\cdot wvd}$	−.79	$r_{pd\cdot wvc}$	−.19
$r_{pw\cdot vcd}$	+.46	$r_{pv\cdot wcd}$	+ 04	$r_{pf\cdot wcd}$	−.83	$r_{pc\cdot wfd}$	−.92	$r_{pd\cdot wfc}$	−.10
$r_{pw\cdot fcd}$	+.83	$r_{pv\cdot fcd}$	+.65	$r_{pf\cdot vcd}$	−.74	$r_{pc\cdot vfd}$	−.83	$r_{pd\cdot vfc}$	+.06
$r_{pw\cdot vfcd}$	+.97	$r_{pv\cdot wfcd}$	+.94	$r_{pf\cdot wvcd}$	−.98	$r_{pc\cdot wvfd}$	−.98	$r_{pd\cdot wvfc}$	+.77

Weight (*w*) and Value per hundredweight (*v*).		Weight (*w*) and Value of feed (*f*).		Weight (*w*) and Cost at weaning time (*c*).		Weight (*w*) and Date of sale (*d*).		Value per hundredweight (*v*) and Value of feed (*f*).	
r_{wv}	+0.56	r_{wf}	+0.51	r_{wc}	+0.07	r_{wd}	+0.60	r_{vf}	+0.65
$r_{wv\cdot p}$	+.53	$r_{wf\cdot p}$	+.63	$r_{wc\cdot p}$	+.42	$r_{wd\cdot p}$	+.59	$r_{vf\cdot p}$	+.76
$r_{wv\cdot f}$	+.35	$r_{wf\cdot v}$	+.23	$r_{wc\cdot v}$	+.15	$r_{wd\cdot v}$	+.39	$r_{vf\cdot w}$	+.51
$r_{wv\cdot c}$	+ 57	$r_{wf\cdot c}$	+.51	$r_{wc\cdot f}$	+.08	$r_{wd\cdot f}$	+.49	$r_{vf\cdot c}$	+.66
$r_{wv\cdot d}$	+.31	$r_{wf\cdot d}$	+.36	$r_{wc\cdot d}$	+.12	$r_{wd\cdot c}$	+.60	$r_{vf\cdot d}$	+.55
$r_{wv\cdot pf}$	+.10	$r_{wf\cdot pv}$	+.42	$r_{wc\cdot pv}$	+.42	$r_{wd\cdot pv}$	+.40	$r_{vf\cdot pw}$	+.65
$r_{wv\cdot pc}$	+.53	$r_{wf\cdot pc}$	+.86	$r_{wc\cdot pf}$	+.81	$r_{wd\cdot pf}$	+.42	$r_{vf\cdot pc}$	+.84
$r_{wv\cdot pd}$	+.28	$r_{wf\cdot pd}$	+.50	$r_{wc\cdot pd}$	+.45	$r_{wd\cdot pc}$	+.61	$r_{vf\cdot pd}$	+.68
$r_{wv\cdot fc}$	+.36	$r_{wf\cdot vc}$	+.22	$r_{wc\cdot vf}$	+.13	$r_{wd\cdot vf}$	+.39	$r_{vf\cdot wc}$	+.52
$r_{wv\cdot fd}$	+.14	$r_{wf\cdot vd}$	+.24	$r_{wc\cdot vd}$	+.16	$r_{wd\cdot vc}$	+.39	$r_{vf\cdot wd}$	+.50
$r_{wv\cdot cd}$	+.32	$r_{wf\cdot cd}$	+.36	$r_{wc\cdot fd}$	+.12	$r_{wd\cdot fc}$	+.50	$r_{vf\cdot cd}$	+.56
$r_{wv\cdot pfc}$	−.67	$r_{wf\cdot pvc}$	+.88	$r_{wc\cdot pvf}$	+.89	$r_{wd\cdot pvf}$	+.42	$r_{vf\cdot pwc}$	+.88
$r_{wv\cdot pfd}$	−.09	$r_{wf\cdot pvd}$	+.44	$r_{wc\cdot pvd}$	+.45	$r_{wd\cdot pvc}$	+.43	$r_{vf\cdot pwd}$	+.65
$r_{wv\cdot pcd}$	+.27	$r_{wf\cdot pcd}$	+.80	$r_{wc\cdot pfd}$	+.79	$r_{wd\cdot pfc}$	+.36	$r_{vf\cdot pcd}$	+.77
$r_{wv\cdot fcd}$	+.16	$r_{wf\cdot vcd}$	+.22	$r_{wc\cdot vfd}$	+.14	$r_{wd\cdot vfc}$	+.40	$r_{vf\cdot wcd}$	+.50
$r_{wv\cdot pfcd}$	−.90	$r_{wf\cdot pvcd}$	+.97	$r_{wc\cdot pvfd}$	+.96	$r_{wd\cdot pvfc}$	+.81	$r_{vf\cdot pwcd}$	+.97

Value per hundredweight (*v*) and Cost at weaning time (*c*).		Value per hundredweight (*v*) and Date of sale (*d*).		Value of feed (*f*) and Cost at weaning time (*c*).		Value of feed (*f*) and Date of sale (*d*).		Cost at weaning time (*c*) and Date of sale (*d*).	
r_{vc}	−0.09	r_{vd}	+0.61	r_{fc}	+0.01	r_{fd}	+0 42	r_{cd}	−0.04
$r_{vc\cdot p}$	+.12	$r_{vd\cdot p}$	+.60	$r_{fc\cdot p}$	−.28	$r_{fd\cdot p}$	+.48	$r_{cd\cdot p}$	+.09
$r_{vc\cdot w}$	−.16	$r_{vd\cdot w}$	+.41	$r_{fc\cdot w}$	−.03	$r_{fd\cdot w}$	+.16	$r_{cd\cdot w}$	−.11
$r_{vc\cdot f}$	−.13	$r_{vd\cdot f}$	+.49	$r_{fc\cdot v}$	+.10	$r_{fd\cdot v}$	+.03	$r_{cd\cdot v}$	+.02
$r_{vc\cdot d}$	−.08	$r_{vd\cdot c}$	+.61	$r_{fc\cdot d}$	+.04	$r_{fd\cdot c}$	+.42	$r_{cd\cdot f}$	−.05
$r_{vc\cdot pw}$	−.14	$r_{vd\cdot pw}$	+.42	$r_{fc\cdot pw}$	−.79	$r_{fd\cdot pw}$	+.17	$r_{cd\cdot pw}$	−.21
$r_{vc\cdot pf}$	+.54	$r_{vd\cdot pf}$	+.41	$r_{fc\cdot pv}$	−.58	$r_{fd\cdot pv}$	+.04	$r_{cd\cdot pv}$	+.03
$r_{vc\cdot pd}$	+.08	$r_{vd\cdot pc}$	+.59	$r_{fc\cdot pd}$	−.37	$r_{fd\cdot pc}$	+.53	$r_{cd\cdot pf}$	+.27
$r_{vc\cdot wf}$	−.17	$r_{vd\cdot wf}$	+.39	$r_{fc\cdot wv}$	+.07	$r_{fd\cdot wv}$	−.07	$r_{cd\cdot wv}$	−.05
$r_{vc\cdot wd}$	−.13	$r_{vd\cdot wc}$	+.40	$r_{fc\cdot wd}$	−.01	$r_{fd\cdot wc}$	+.16	$r_{cd\cdot wf}$	−.10
$r_{vc\cdot fd}$	−.12	$r_{vd\cdot fc}$	+.48	$r_{fc\cdot vd}$	+.10	$r_{fd\cdot vc}$	+.03	$r_{cd\cdot vf}$	+.01
$r_{vc\cdot pwf}$	+.77	$r_{vd\cdot pwf}$	+.41	$r_{fc\cdot pwv}$	−.92	$r_{fd\cdot pwv}$	−.15	$r_{cd\cdot pwv}$	−.18
$r_{vc\cdot pwd}$	−.05	$r_{vd\cdot pwc}$	+.40	$r_{fc\cdot pwd}$	−.77	$r_{fd\cdot pwc}$	+.01	$r_{cd\cdot pwf}$	−.13
$r_{vc\cdot pfd}$	+.49	$r_{vd\cdot pfc}$	+.33	$r_{fc\cdot pvd}$	−.58	$r_{fd\cdot pvc}$	+.07	$r_{cd\cdot pvf}$	+.06
$r_{vc\cdot wfd}$	−.14	$r_{vd\cdot wfc}$	+.38	$r_{fc\cdot wvd}$	+.06	$r_{fd\cdot wvc}$	−.06	$r_{cd\cdot wvf}$	−.04
$r_{vc\cdot pwfd}$	+.90	$r_{vd\cdot pwfc}$	+.81	$r_{fc\cdot pwvd}$	−.96	$r_{fd\cdot pwvc}$	−.82	$r_{cd\cdot pwvf}$	−.75

two at a time, had been considered, they were taken three at a time, and finally all four were taken into account simultaneously. In all, 260 of the coefficients were computed. Some of them, however, are of little interest, and if this were simply a study of the data, and not also an exposition of the method used, the computation of some of them might have been omitted.

In order to avoid needless repetition in the tables, the different factors are designated by letters as follows: Profit=p, weight=w, value per hundredweight=v, value of feed per head=f, cost at weaning time=c, date of sale=d, and the notation for the different coefficients is the same as that used in the explanation of the theory, viz: $r_{ab \cdot cd,\ etc.}$, is the coefficient of correlation between a and b when c, d, etc., are taken into account.

INTERPRETATION OF THE COEFFICIENTS.

There are four factors, namely, initial cost, value of feed consumed, weight, and selling price, which determine almost entirely the profit or loss to the farmer in finishing cattle for market. In fattening baby beef animals, the weight of the calves and the value of feed consumed both depend, to a large extent, on their age when sold and the length of time they were on feed. Also the price per pound received for them is rather intimately connected with the date on which they were sold, prices having had a tendency to rise as the season advanced. The calves for which data were gathered were all born in the spring, went on feed in the fall or early winter, and were sold some time during the following year. Consequently, any one of the three factors, age, length of feeding period, and date of sale, is a very good measure of the other two, and on account of this only the date of sale has been considered.

If the price per pound, value of feed, initial cost, and date of sale were constant, and if nothing else affected the profit, it would vary directly with the weight in every case and, according to the theory, the coefficient of correlation between the two should be +1. The coefficient, $r_{pw \cdot vfcd}$, obtained here is +.97. Similarly, if all things were constant except value per hundredweight and profit, there would be perfect positive correlation between them. The net coefficient, $r_{pv \cdot wfcd}$, given in Table III is +.94. If all things were constant except the value of feed consumed we should expect a high negative correlation between it and profit, i. e., the calf that received the least feed would return the greatest profit. The net coefficient, $r_{pf \cdot wvcd}$, is —.98. Similarly, other things being equal, perfect negative correlation should exist between initial cost and profit. The net coefficient in this case, $r_{pc \cdot wvfd}$, is also —.98. An examination of the remainder of these net coefficients, which are the last ones given in the table, will show that, with the exception of the five between date of sale and the other variables, they are all numerically equal to or above .90. It has been shown that part, but not all, of the correlation between weight and price was due to the date of sale, and since date of sale is only an approximate measure of age and length of feeding period, it would not be reasonable to expect the net correlation between it and the other variables to be perfect. The fact that all the net coefficients except these five are so nearly +1 or —1, when there was every reason to expect perfect correlation, is striking proof of the reliability of this method of analysis as well as of the accuracy of data such as those under consideration, and is at the same time a very good check on the computations.

In the interpretation of the coefficients care must be taken to distinguish between subjective and relative factors, i. e., between cause and effect. Most interest is naturally attached to determining to just what extent each of the factors under consideration is responsible for the farmer's loss or gain in his baby-beef enterprise, and here there can be no confusion of cause and effect, for all the other factors are necessarily causative. Throughout the remainder of the investigation the amount of profit or loss is an effect and not a cause, and consequently too much weight should not be given to a coefficient in which the effect of profit has been taken into account.

THE APPARENT CORRELATIONS.

In taking up the discussion of the coefficients themselves, the apparent correlations between profit and the other five factors are first considered:

Coefficients of correlation.

Profit and Weight.	Profit and Value per hundredweight.	Profit and Value of feed,	Profit and Cost at weaning time.	Profit and Date of sale.
+.28	+.23	—.27	—.73	+.14

These five coefficients should show the average effect of each of the five factors on the profit. The coefficient for profit and date of sale (+.14) shows that the profit on the calves sold early in the season was practically as great as on those sold later. The first three are all of nearly the same size, but are too small to indicate more than slight relationship. In regard to them we may say, therefore, that in the data under consideration: (1) There was a tendency for the heavier calves to return a greater profit; (2) there is some correlation between price per pound and profit; (3) generally speaking, the farmer whose calves consumed feed worth more than the average made a profit somewhat less than the average.

A very high degree of correlation between profit and cost at weaning time is shown by the coefficient —.73, and, as would be expected, it is negative. The size of this coefficient as compared to the others indicates that the cost of producing the calves and carrying them until weaning time is by far the most important factor in determining the profit derived by any particular farmer from the production of baby beef. In all of the records considered the calves were with the cows until they went on feed, and there was no expense directly chargeable to them. Bearing this in mind, the further statement is justified that the cost of maintaining the breeding herd and the size of the calf crop have considerably more to do with the profitableness of the enterprise than the actual preparation of the calves for market.

Coefficients of correlation between weight and factors other than profit.

Weight and Value per hundredweight.	Weight and Value of feed.	Weight and Cost at weaning time.	Weight and Date of sale.
+.56	+.51	+.07	+.60

The coefficient +.07, for weight and cost at weaning time, is the most striking one given here. Its very small size shows that there is no connection between the cost of the calves up to the time they went on feed and the weights at which they were sold. The cost of a calf at weaning time is determined very largely by the manner in which the breeding herd is handled, and consequently this coefficient shows further that on the farms studied the calves from the herds which were maintained at a low cost per head weighed just as much when sold as did those from herds having a high maintenance cost. The coefficients for weight and value of feed and weight and date of sale are what should normally be expected. The calves that received more feed than the average weighed more than the average, and the ones that were sold in the latter part of the season also weighed more than the average. The high correlation, exhibited by the coefficient +.56, between weight and price per pound is a surprising one, but it will be shown later that it is almost entirely due to the mutual correlation of these two factors with some of the others.

The gross coefficient for value per hundredweight and value of feed,[1] +.65, shows another apparently high correlation which may or may not disappear when some of the other factors are taken into account. There is no correlation between value per hundredweight and cost at weaning time. The correlation between value per pound and date of sale is shown by the coefficient +.61, which confirms

[1] For this and all coefficients mentioned hereafter, see Table III.

the statement already made that the price was generally higher later in the season. The remaining gross coefficients are +.01 for total value of feed consumed per head and cost at weaning time, +.42 for value of feed consumed and date of sale, and —.04 for cost at weaning time and date of sale. The coefficients +.01 and —.04 show that cost at weaning time is uncorrelated with either value of feed consumed or date of sale. With regard to the correlation between value of feed consumed per head and date of sale, we may say that the value of feed consumed is probably very nearly proportional to the length of the feeding period, and if the actual length of time on feed had been used here instead of its approximate measure, the date of sale, the correlation would probably have been higher.

EFFECT OF THE OTHER FACTORS ON THE APPARENT CORRELATIONS.

The small degree of correlation present between profit and weight is mostly due to differences in price, the coefficient being reduced from +.28 to +.18, when the value per hundredweight is taken into account; that is to say, the tendency of the heavier calves to be the more profitable is mostly due to the fact that they sold for a better price per pound than that commanded by the smaller calves.

The coefficient $r_{pw.f}$ is +.50, which is considerably higher than the gross coefficient, showing that if the value of feed had been constant while other things remained unchanged, the correlation between profit and weight would have been greater.

The correct explanation of the size of the coefficient $r_{pw.c}$, which is +.48, is not so apparent. It indicates, however, that if the influence of the cost at weaning time, the factor most closely related to profit, were eliminated, the correlation between profit and weight would be greater.

When the date of sale is taken into account, the correlation between profit and weight becomes somewhat less than the gross correlation, but the difference is not enough to be significant.

The coefficients obtained for the correlation between weight and profit, when the effect of the other factors, two at a time, is considered, are generally higher than when they are considered one at a time. This means that if the influence of two of the factors contributing to the profit or loss is eliminated, its correlation with any of the remaining factors is higher than if the influence of but one had been eliminated.

It is interesting to note here that the correlation between weight and profit, even when the other factors are taken into account, is almost entirely independent of the date of sale. The apparent correlation, +.28, becomes +.24 when date of sale is taken into account. When value per pound is taken into account, the coefficient is +.18; when price and date of sale are considered simultaneously, the coefficient is +.20. Similarly, $r_{pw.f} = +.50$, and $r_{pw.fd} = +.43$; $r_{pw.c} = +.48$, and $r_{pw.cd} = +.49$; $r_{pw.vf} = +.39$, and $r_{pw.vfd} = +.42$; $r_{pw.vc} = +.43$, and $r_{pw.vcd} = +.46$; $r_{pw.fc} = +.85$, and $r_{pw.fcd} = +.83$; $r_{pw.vfc} = +.91$, and $r_{pw.vfcd} = +.97$.

The remainder of the coefficients will not be taken up in detail, for the same reasoning may be applied as has been used for those between profit and weight. The notation is consistent throughout, and the arrangement is such that any desired coefficient can be found.

There does not seem to be any relation between cost at weaning time and any of the other factors considered except profit, and since cost at weaning time had more influence on profit than any of the others, it might be of interest to know the relationship that would have existed between profit and the other factors if the initial cost had been constant.

The coefficients are as follows:

$r_{pw.c}$	$r_{pv.c}$	$r_{pf.c}$	$r_{pd.c}$
+.48	+.25	−.38	+.16

From these coefficients, it is evident that if the initial cost of all the calves had been the same, the most important factor in determining the profit would have been the weight when marketed; the other factors in the order of their importance being the total value of feed consumed, the price per pound, and the date of sale. However, the correlation between profit and date of sale is still too small to be important.

The statement has already been made that the apparent correlation between weight and value per hundredweight ($r=+.56$) is due to the effect of other factors. A study of the coefficients obtained when these other factors are taken into consideration shows that when the influence of date of sale is eliminated, the coefficient is reduced to +.31; when the influence of the value of feed consumed is eliminated, the coefficient becomes +.35; and when the two factors are taken into account simultaneously, the coefficient is +.14. This shows that the quantity of feed consumed per head was responsible for nearly as much of this correlation as was the date of sale, and that the two together account for practically the whole of it. In other words, the value of feed consumed and the date of sale need to be considered simultaneously here, because the later the date of sale, the longer is the feeding period, and consequently the greater the quantity and value of feed consumed.

The gross correlation between date of sale and value per pound is shown by the coefficient +.61, and that between total value of feed consumed per head and value per pound, by the coefficient +.65.

These rather large coefficients become very little smaller when all the other causal factors are taken into account. Therefore, there must be some relationship existing between value per pound and date of sale, and value per pound and value of feed consumed. The reason for the correlation between value per pound and date of sale has already been given. It is probable that the reason for the high correlation between the value per pound and value of feed consumed is due to the fact that the calves which were fed the heaviest ration, regardless of the length of feeding period, were the fattest when marketed, and consequently sold at a higher price. However, the relation between the profit and value of feed consumed per head as measured by the correlation coefficient r_{pf} is —.27, and when the influence of a longer feeding period is taken into account by eliminating the effect of date of sale the correlation is still negative ($r_{pf \cdot d} = -.37$).

SUMMARY.

The results show that data such as those obtained by farm management surveys can be analyzed very thoroughly by the use of the correlation coefficients. It is generally known before the analysis is attempted which factors are causal and which resultant, and consequently there should be very little difficulty in interpreting the coefficients correctly. The coefficients of net correlation afford a very good means of determining the net effect of each of several factors bearing upon a result, or of eliminating the effect of other factors when it is desired to find the true relationship existing between any two. Although it is not possible to give a definite concrete meaning to correlation coefficients, they are very concise relative measures of the degree of relationship existing between the factors being studied. They therefore give the investigator a single index which will show what, by the ordinary tabular method, it takes a whole table to show. While properly constructed tables will show whether or not any relationship exists between two factors, it is a difficult matter to determine which of two causes, say, has the greater effect on the result, and it is impossible, without a large number of records and a great amount of sorting and tabulation, to separate all the factors being considered in a study and find the effect that each one would have had if the others had not been present, or if they had been constant throughout the investigation. If the gross coefficients of correlation between every pair of factors have been determined, it is possible to find these relationships by simply substituting in the formula for determining a net coefficient from the gross coefficients, without any further reference to the records themselves. This method should be especially useful if only a limited number of records or observations are available, for it does away with the necessity of sorting into many groups, with the consequent falling off in the reliability of the averages obtained.

The analysis of the data on fattening baby beef animals showed:

(1) That for the herds considered, the cost of producing the calves and carrying them until weaning time was by far the most important factor in determining the profit;

(2) That there was no connection between the cost at weaning time and any of the other factors, for the calves which were produced cheaply were seemingly just as good feeders and brought just as good a price per pound as the more expensive ones;

(3) That the weight at which the calves were sold and the date of sale had very little effect on the profit, except for the fact that in the two years of the records the price was higher in the latter part of the summer, at the time when the heavier calves were put on the market;

(4) That the calves which consumed the heaviest ration sold at higher prices than the others, but did not return a correspondingly greater profit, as the advanced price scarcely offset the extra value of feed consumed.

OTHER PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO THE SUBJECT OF THIS BULLETIN.

Elementary Notes on Least Squares, the Theory of Statistics and Correlation, for Meteorology and Agriculture. (Monthly Weather Review, vol. 44, 1916, p. 551.)

Effect of Weather on Yield of Potatoes. (Monthly Weather Review, vol. 43, 1915, p. 232.)

Effect of Weather on Yield of Corn. (Monthly Weather Review, vol. 42, 1914, p. 72.)

Methods and Cost of Growing Beef Cattle in the Corn Belt States. (Report No. 111, Office of the Secretary.)

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DIGESTIBILITY OF SOME VEGETABLE FATS.

By C. F. LANGWORTHY, *Chief*, and A. D. HOLMES, *Scientific Assistant, Office of Home Economics.*

CONTENTS.

INTRODUCTION.

Studies of the digestibility of some common animal fats, including lard, beef fat, mutton fat, and butter, have been reported in a previous paper [1] of this series. The results of these experiments showed that all the animal fats investigated were satisfactorily digested and are suitable for use in quantity as food.

The available supply of animal fats, however, is now little if any in excess of the demand, and it is likely that the supply of such fats for culinary purposes in the future will be even less adequate than at the present time. It is probable, therefore, that in the future greater reliance must be placed on the vegetable fats to supplement the available animal-fat supply. The experiments reported in this bulletin, showing the thoroughness of digestion of certain vegetable oils and indicating in a general way their suitability for food, have an important bearing on this question. The fats studied included olive oil, cottonseed oil, peanut oil, coconut oil, sesame oil, and cocoa butter.

EXPERIMENTAL METHODS.

The digestion experiments with the vegetable fats were conducted by the same methods that were employed in the study of the animal fats, and accordingly the results are directly comparable. A basal

[1] U. S. Dept. Agr. Bul. 310 (1915).

NOTE.—This bulletin records studies of the digestibility of olive oil, cottonseed oil, peanut oil, coconut oil, sesame oil, and cocoa butter, and is primarily of interest to students and investigators of food problems.

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ration (supplying a minimum of fat) composed of wheat biscuits, oranges, sugar, and tea, or coffee if desired, was supplemented by a blancmange or cornstarch pudding, in which was incorporated the vegetable fat under consideration.

The test periods were of three days' or nine meals' duration, to agree with the experimental conditions under which the animal fats were studied, and the following four days formed a rest period in which the subjects furnished their own meals, which differed in no special way from an ordinary mixed diet.

Normal young men in good health and moderately active, all of whom were medical or dental students, were the subjects of the digestion experiments. The prescribed routine involved regularity, especially with respect to the time for eating, but the subjects were permitted to exercise in their customary ways and as required in the performance of their daily work. In most cases the subjects had had previous experience in similar experiments, and all of them proved to be careful and trustworthy assistants.

Weighings were made of the net amounts of food eaten and feces excreted, and samples of both food and feces were analyzed to determine the percentages of protein, fat, and carbohydrate which were actually digested.

The experimental method followed has been reported in a previous bulletin of this series,[1] the analytical methods being those which are approved by the Association of Official Agricultural Chemists.[2]

DIGESTION EXPERIMENTS.

OLIVE OIL.

Although olive oil has been known from earliest times as a food product, exact information regarding the proportion assimilated by the body is comparatively limited, its food value having been generally discussed with respect to its theoretical energy value, its quality, and culinary and table uses. As regards earlier work, a five-day experiment with a healthy man was conducted by Bertarelli,[3] who tested the digestibility of a mixture of olive and colza oils in a basal ration of white bread and meat; the fat was 95.8 per cent digested. Moore [4] has reported a number of animal feeding experiments in which he found that olive oil was assimilated to the extent of from 96.7 to 98.7 per cent. In a comparative series of tests he noticed that uncooked oils in the food of guinea pigs were somewhat less thoroughly available than was the case when the oil was cooked with the food. In general all of the vegetable fats studied were digested to practically the same extent.

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[1] U. S. Dept. Agr. Bul. 310 (1915).
[2] U. S. Dept. Agr., Bur. Chem. Bul. 107 (1912), rev. ed.
[3] Riv. Ig. e Sanit. Pub., 9 (1898), Nos. 14, pp. 538–545; 15, pp. 570–579.
[4] Arkansas Sta. Bul. 78 (1903), pp. 33–41.

Arnschink[1] reports an experiment of four days' duration with a dog of 8 kilograms body weight. Fifty grams of olive oil was consumed daily and 97.77 per cent digested.

Olive oil has been studied from another viewpoint, namely, its ability, as compared with certain animal fats such as butter and cod liver oil, to maintain growth. Work along these lines has been reported by Osborne and Mendel[2] and McCollum and Davis,[3] who concluded that olive oil was not capable of stimulating or maintaining growth.

In experiments here reported five subjects took part in the 11 digestion experiments, the results of which are given in the following tables:

Data of digestion experiments with olive oil in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 151, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing olive oil	1,579.0	734.7	26.7	192.6	618.4	6.6
Wheat biscuit	633.0	57.0	67.1	9.5	489.3	10.1
Fruit	803.0	697.8	6.4	1.6	93.2	4.0
Sugar	191.0				191.0	
Total food consumed	3,206.0	1,489.5	100.2	203.7	1,391.9	20.7
Feces	114.5		30.6	10.0	65.4	8.5
Amount utilized			69.6	193.7	1,326.5	12.2
Per cent utilized			69.5	95.1	95.3	58.9
Experiment No. 153, subject R. L. S.:						
Blancmange containing olive oil	1,587.0	738.4	26.8	193.6	621.6	6.6
Wheat biscuit	417.0	37.5	44.2	6.3	322.3	6.7
Fruit	810.0	703.9	6.5	1.6	94.0	4.0
Sugar	91.0				91.0	
Total food consumed	2,905.0	1,479.8	77.5	201.5	1,128.9	17.3
Feces	102.5		31.4	17.2	44.1	9.8
Amount utilized			46.1	184.3	1,084.8	7.5
Per cent utilized			59.5	91.5	96.1	43.4
Experiment No. 154, subject R. F. T.:						
Blancmange containing olive oil	1,865.0	867.8	31.5	227.5	730.4	7.8
Wheat biscuit	46.0	4.1	4.9	.7	35.6	.7
Fruit	1,283.0	1,114.9	10.3	2.6	148.8	6.4
Sugar	132.0				132.0	
Total food consumed	3,326.0	1,986.8	46.7	230.8	1,046.8	14.9
Feces	69.5		16.4	14.6	32.1	6.4
Amount utilized			30.3	216.2	1,014.7	8.5
Per cent utilized			64.9	93.7	96.9	57.0
Experiment No. 183, subject D. G. G.:						
Blancmange containing olive oil	1,127.0	494.0	21.1	138.8	465.1	8.0
Wheat biscuit	561.0	50.5	59.5	8.4	433.6	9.0
Fruit	775.0	673.5	6.2	1.5	89.9	3.9
Sugar	209.0				209.0	
Total food consumed	2,672.0	1,218.0	86.8	148.7	1,197.6	20.9
Feces	69.0		21.4	7.5	34.2	5.9
Amount utilized			65.4	141.2	1,163.4	15.0
Per cent utilized			75.3	95.0	97.1	71.8

[1] Ztschr. Biol., 26 (1890), No. 4, pp. 444, 445.

[2] Jour. Biol. Chem., 16 (1913), No. 3, pp. 423–437.

[3] Idem, 15 (1913), No. 1, pp. 167–175; 19 (1914), No. 2, pp. 245–250; 20 (1915), No. 4, pp. 641–658; 21 (1915), No. 1, pp. 179–182. Wisconsin Sta. Bul. 240 (1914), pp. 33, 34.

Data of digestion experiments with olive oil in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 184, subject R. L. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing olive oil	1,827.0	800.8	34.1	225.1	754.0	13.0
Wheat biscuit	314.0	28.3	33.3	4.7	242.7	5.0
Fruit	1,347.0	1,170.5	10.8	2.7	156.3	6.7
Sugar	122.0	....	....	....	122.0	....
Total food consumed	3,610.0	1,999.6	78.2	232.5	1,275.0	24.7
Feces	64.0	....	20.3	10.9	27.2	5.6
Amount utilized	....	....	57.9	221.6	1,247.8	19.1
Per cent utilized	....	....	74.0	95.3	97.9	77.3
Experiment No. 185, subject O. E. S.:						
Blancmange containing olive oil	1,958.0	858.2	36.6	241.2	808.1	13.9
Wheat biscuit	153.0	13.8	16.2	2.3	118.3	2.4
Fruit	1,568.0	1,362.6	12.6	3.1	181.9	7.8
Sugar	188.0	....	....	....	188.0	....
Total food consumed	3,867.0	2,234.6	65.4	246.6	1,296.3	24.1
Feces	42.0	....	12.6	5.1	20.5	3.8
Amount utilized	....	....	52.8	241.5	1,275.8	20.3
Per cent utilized	....	....	80.7	97.9	98.4	84.2
Experiment No. 186, subject R. F. T.:						
Blancmange containing olive oil	1,322.0	579.4	24.7	162.9	545.6	9.4
Wheat biscuit	91.0	8.2	9.6	1.4	70.3	1.5
Fruit	1,485.0	1,290.5	11.9	3.0	172.2	7.4
Sugar	183.0	....	....	....	183.0	....
Total food consumed	3,081.0	1,878.1	46.2	167.3	971.1	18.3
Feces	70.0	....	17.5	10.9	33.6	8.0
Amount utilized	....	....	28.7	156.4	937.5	10.3
Per cent utilized	....	....	62.1	93.5	96.5	56.3
Experiment No. 243, subject D. G. G.:						
Blancmange containing olive oil	2,321.0	985.0	43.6	266.5	1,014.3	11.6
Wheat biscuit	500.0	45.0	53.0	7.5	386.5	8.0
Fruit	1,202.0	1,044.6	9.6	2.4	139.4	6.0
Sugar	120.0	....	....	....	120.0	....
Total food consumed	4,143.0	2,074.6	106.2	276.4	1,660.2	25.6
Feces	131.0	....	37.3	12.7	71.5	9.5
Amount utilized	....	....	68.9	263.7	1,588.7	16.1
Per cent utilized	....	....	64.9	95.4	95.7	62.9
Experiment No. 244, subject R. L. S.:						
Blancmange containing olive oil	2,143.0	909.5	40.3	246.0	936.5	10.7
Wheat biscuit	437.0	39.3	46.3	6.6	337.8	7.0
Fruit	546.0	474.5	4.4	1.1	63.3	2.7
Sugar	85.0	....	....	....	85.0	....
Total food consumed	3,211.0	1,423.3	91.0	253.7	1,422.6	20.4
Feces	84.0	....	24.7	11.2	41.8	6.3
Amount utilized	....	....	66.3	242.5	1,380.8	14.1
Per cent utilized	....	....	72.9	95.6	97.1	69.1
Experiment No. 245, subject O. E. S.:						
Blancmange containing olive oil	2,690.0	1,141.6	50.6	308.8	1,175.6	13.4
Wheat biscuit	497.0	44.7	52.7	7.5	384.2	7.9
Fruit	1,228.0	1,067.1	9.8	2.5	142.5	6.1
Sugar	177.0	....	....	....	177.0	....
Total food consumed	4,592.0	2,253.4	113.1	318.8	1,879.3	27.4
Feces	126.0	....	33.4	17.8	66.7	8.1
Amount utilized	....	....	79.7	301.0	1,812.6	19.3
Per cent utilized	....	....	70.5	94.4	96.5	70.4
Average food consumed per subject per day	1,153.8	601.3	27.0	76.0	442.3	7.2

Summary of digestion experiments with olive oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
151	D. G. G	69.5	95.1	95.3	58.9
153	R. L. S	59.5	91.5	96.1	43.4
154	R. F. T	64.9	93.7	96.9	57.0
183	D. G. G	75.3	95.0	97.1	71.8
184	R. L. S	74.0	95.3	97.9	77.3
185	O. E. S	80.7	97.9	98.4	84.2
186	R. F. T	62.1	93.5	96.5	56.3
243	D. G. G	64.9	95.4	95.7	62.9
244	R. L. S	72.9	95.6	97.1	69.1
245	O. E. S	70.5	94.4	96.5	70.4
	Average	69.4	94.7	96.8	65.1

The average coefficient of digestibility of all the fat eaten during these tests was 94.7. As the ether extract of the feces, however, is known to contain metabolic products, a correction has been applied to all of the value for the average availability of total fat consumed. Digestion experiments with the basal ration alone as the only source of fat have been reported in connection with the animal-fat experiments, from which it was concluded that 9.89 per cent of the total weight of water-free feces occurs as metabolic products.[1] Subtracting the quantity represented by this percentage from the total ether extract of the feces, a value is obtained more nearly representing the weight of unutilized fat. The corrected value for the availability of olive oil then becomes 97.8 per cent.

The five subjects reported that they remained in normal physical condition during the experimental periods. In experiment No. 185, in which 80 grams of olive oil was eaten per day, the subject O. E. S. reported that the diet had a constipating effect. In experiments Nos. 243, 244, and 245, in which 82, 89, and 103 grams of olive oil were consumed, the subjects reported that the diet produced a pronounced laxative effect. However, in the experiments in which the laxative effect was noted, the olive oil was as completely assimilated as in the remaining experiments, and the tests as a whole yield additional evidence that, used in the usual ways for cooking and on the table, olive oil is a wholesome, valuable food.

COTTONSEED OIL.

Refined cottonseed oil is a common food product used as such in large quantities for culinary and table purposes, and also in the manufacture of hardened fats and other commercial fats designed for use in cookery.

Very few results have been found on record which concern the digestibility of cottonseed oil by the human organism, though animal feeding experiments have been rather common. Moore [2] has reported

[1] U. S. Dept. Agr. Bul. 310 (1915), p. 20.

[2] Loc. cit.

experiments intended to compare the digestibilities of several of the more common vegetable fats, concluding that all vegetable fats are equally well digested.

The experiments made at this time concern only the actual percentage of fat available to the body, though it might be possible at the same time to notice approximately how much of the oil can be used without producing a laxative effect or other physiological disturbances. Six subjects assisted in the work, and the same methods were used which hitherto have proved entirely satisfactory. The data describing the results of the 12 test periods are as follows:

Data of digestion experiments with cottonseed oil in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 139, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing cottonseed oil.	1,915.0	913.4	32.6	264.3	697.1	7.6
Wheat biscuit	722.0	65.0	76.5	10.8	558.1	11.6
Fruit	1,351.0	1,174.0	10.8	2.7	156.7	6.8
Sugar	66.0				66.0	
Total food consumed	4,054.0	2,152.4	119.9	277.8	1,477.9	26.0
Feces	102.0		27.5	11.7	53.6	9.2
Amount utilized			92.4	266.1	1,424.3	16.8
Per cent utilized			77.0	95.8	96.4	64.6
Experiment No. 140, subject H. D. G.:						
Blancmange containing cottonseed oil.	1,148.0	547.6	19.5	158.4	417.9	4.6
Wheat biscuit	598.0	53.8	63.4	9.0	462.2	9.6
Fruit	1,274.0	1,107.1	10.2	2.5	147.8	6.4
Sugar	96.0				96.0	
Total food consumed	3,116.0	1,708.5	93.1	169.9	1,123.9	20.6
Feces	100.5		26.7	10.4	53.3	10.1
Amount utilized			66.4	159.5	1,070.6	10.5
Per cent utilized			71.3	93.9	95.3	51.0
Experiment No. 141, subject R. L. S.:						
Blancmange containing cottonseed oil.	1,495.0	713.1	25.4	206.3	544.2	6.0
Wheat biscuit	444.0	40.0	47.1	6.6	343.2	7.1
Fruit	1,246.0	1,082.8	10.0	2.5	144.5	6.2
Sugar	119.0				119.0	
Total food consumed	3,304.0	1,835.9	82.5	215.4	1,150.9	19.3
Feces	87.0		28.0	18.1	31.3	9.6
Amount utilized			54.5	197.3	1,119.6	9.7
Per cent utilized			66.1	91.6	97.3	50.3
Experiment No. 142, subject R. F. T:						
Blancmange containing cottonseed oil.	2,099.0	1,001.2	35.7	289.7	764.0	8.4
Wheat biscuit	110.0	9.9	11.7	1.6	85.0	1.8
Fruit	1,304.0	1,133.2	10.4	2.6	151.3	6.5
Sugar	85.0				85.0	
Total food consumed	3,598.0	2,144.3	57.8	293.9	1,085.3	16.7
Feces	72.5		16.9	12.3	37.0	6.3
Amount utilized			40.9	281.6	1,048.3	10.4
Per cent utilized			70.8	95.8	96.6	62.3
Experiment No. 143, subject D. G. G.:						
Blancmange containing cottonseed oil.	1,632.0	768.8	32.2	220.8	603.2	7.0
Wheat biscuit	913.0	82.2	96.8	13.7	705.7	14.6
Fruit	957.0	831.6	7.7	1.9	111.0	4.8
Sugar	163.0				163.0	
Total food consumed	3,665.0	1,682.6	136.7	236.4	1,582.9	26.4
Feces	131.3		32.2	11.5	76.5	11.1
Amount utilized			104.5	224.9	1,506.4	15.3
Per cent utilized			76.4	95.1	95.2	58.0

Data of digestion experiments with cottonseed oil in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 144, subject H. D. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing cottonseed oil.	1,241.0	584.6	24.5	167.9	458.7	5.3
Wheat biscuit	775.0	69.8	82.1	11.6	599.1	12.4
Fruit	1,118.0	971.5	9.0	2.2	129.7	5.6
Sugar	178.0				178.0	
Total food consumed	3,312.0	1,625.9	115.6	181.7	1,365.5	23.3
Feces	121.5		37.8	11.4	60.4	11.9
Amount utilized			77.8	170.3	1,305.1	11.4
Per cent			67.3	93.7	95.6	48.9
Experiment No. 145, subject R. L. S.:						
Blancmange containing cottonseed oil.	1,497.0	705.3	29.5	202.5	553.3	6.4
Wheat biscuit	359.0	32.3	38.1	5.4	277.5	5.7
Fruit	1,266.0	1,100.2	10.1	2.5	146.9	6.3
Sugar	76.0				76.0	
Total food consumed	3,198.0	1,837.8	77.7	210.4	1,053.7	18.4
Feces	91.9		25.7	14.0	43.5	8.7
Amount utilized			52.0	196.4	1,010.2	9.7
Per cent utilized			66.9	93.3	95.9	52.7
Experiment No. 146, subject R. F. T.:						
Blancmange containing cottonseed oil.	2,112.0	995.0	41.6	285.7	780.6	9.1
Wheat biscuit	114.0	10.3	12.1	1.7	88.1	1.8
Fruit	1,178.0	1,023.7	9.4	2.4	136.6	5.9
Sugar	102.0				102.0	
Total food consumed	3,506.0	2,029.0	63.1	289.8	1,107.3	16.8
Feces	50.8		11.0	9.1	26.8	3.9
Amount utilized			52.1	280.7	1,080.5	12.9
Per cent utilized			82.6	96.9	97.6	76.8
Experiment No. 246, subject H. F. B.:						
Blancmange containing cottonseed oil.	2,602.0	1,082.5	47.5	359.3	1,097.1	15.6
Wheat biscuit	721.0	64.9	76.4	10.8	557.3	11.6
Fruit	1,750.0	1,520.8	14.0	3.5	203.0	8.7
Sugar	209.0				209.0	
Total food consumed	5,282.0	2,668.2	137.9	373.6	2,066.4	35.9
Feces	165.0		40.5	21.2	89.4	13.9
Amount utilized			97.4	352.4	1,977.0	22.0
Per cent utilized			70.6	94.3	95.7	61.3
Experiment No. 247, subject D. G. G.:						
Blancmange containing cottonseed oil.	2,162.0	899.3	39.5	298.6	911.6	13.0
Wheat biscuit	317.0	28.5	33.6	4.8	245.0	5.1
Fruit	1,657.0	1,439.9	13.3	3.3	192.2	8.3
Sugar	169.0				169.0	
Total food consumed	4,305.0	2,367.7	86.4	306.7	1,517.8	26.4
Feces	111.0		52.8	11.0	38.8	8.4
Amount utilized			33.6	295.7	1,479.0	18.0
Per cent utilized			38.9	96.4	97.4	68.2
Experiment No. 248, subject R. L. S.:						
Blancmange containing cottonseed oil.	2,005.0	834.1	36.6	276.9	845.4	12.0
Wheat biscuit	366.0	32.9	38.8	5.5	282.9	5.9
Fruit	1,229.0	1,068.0	9.8	2.5	142.6	6.1
Sugar	89.0				89.0	
Total food consumed	3,689.0	1,935.0	85.2	284.9	1,359.9	24.0
Feces	78.0		37.0	13.4	20.2	7.4
Amount utilized			48.2	271.5	1,339.7	16.6
Per cent utilized			56.6	95.3	98.5	69.2
Experiment No. 249, subject O. E. S.:						
Blancmange containing cottonseed oil.	2,725.0	1,133.6	49.7	376.3	1,149.0	16.4
Wheat biscuit	433.0	39.0	45.9	6.5	334.7	6.9
Fruit	1,745.0	1,516.4	14.0	3.5	202.4	8.7
Sugar	181.0				181.0	
Total food consumed	5,084.0	2,689.0	109.6	386.3	1,867.1	32.0
Feces	106.0		34.2	12.1	51.6	8.1
Amount utilized			75.4	374.2	1,815.5	23.9
Per cent utilized			68.8	96.9	97.2	74.7
Average food consumed per subject per day	1,280.9	685.5	32.4	89.6	465.5	7.9

Summary of digestion experiments with cottonseed oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
139	D. G. G	77.0	95.8	96.4	64.6
140	H. D. G	71.3	93.9	95.3	51.0
141	R. L. S	66.1	91.6	97.3	50.3
142	R. F. T	70.8	95.8	96.6	62.3
143	D. G. G	76.4	95.1	95.2	58.0
144	H. D. G	67.3	93.7	95.6	48.9
145	R. L. S	66.9	93.3	95.9	52.7
146	R. F. T	82.6	96.9	97.6	76.8
246	H. F. B	70.6	94.3	95.7	61.3
247	D. G. G	38.9	96.4	97.4	68.2
248	R. L. S	56.6	95.3	98.5	69.2
249	O. E. S	68.8	96.9	97.2	74.7
	Average	67.8	94.9	96.6	61.5

The average coefficient of digestibility of the fat, of which over 96.3 per cent was cottonseed oil, was 94.9 per cent, while 67.8 per cent of the protein and 96.6 per cent of the carbohydrates were retained in the body. Making allowance for that portion of the ether extract designated metabolic products the actual availability of the cottonseed oil becomes 97.6 per cent. In 9 of the 12 experiments the subjects reported that the feces were of a normal consistency. In experiments Nos. 142 and 247, in which 94 and 98 grams of cottonseed oil was consumed, the subjects reported that the feces were softer than normal. In experiment No. 249, however, in which 125 grams of cottonseed oil was eaten daily, the subject reported the diet as being constipating. Accordingly, it would seem that cottonseed oil does not act as a laxative when eaten in amounts not exceeding 125 grams daily. In view of the fact that 86 grams of cottonseed oil was eaten by each subject daily without digestive disturbances of any kind it is reasonable to conclude that cottonseed oil may be used freely for culinary or table purposes.

PEANUT OIL.

The total quantity of peanuts eaten is very large and it follows that the amount of oil eaten as an integral part of the nuts is also large. The partially separated oil as it occurs in peanut butter is easily recognized, and this, too, is eaten in quantity. The expressed oil has long been known for culinary and table purposes, and its use has increased in the United States as the methods of manufacture have improved.

The only investigations of the food value of peanut oil of which accounts have been found in the literature are those of Moore [1] on the relative digestibility of various edible fats and oils of vegetable origin, which showed that peanut oil was 86 per cent digested by guinea pigs.

Part of the oil used in the experiments reported in this bulletin was prepared by the Bureau of Chemistry of the United States Department of Agriculture, and the remainder was purchased in the open market. That obtained from the Bureau of Chemistry was

[1] Loc. cit.

manufactured in its laboratories, and being freshly made was judged to be of most excellent quality. The commercial samples were much older, but were considered excellent in odor, flavor, and color. There was no apparent difference in the flavor of the two samples, which would seem to indicate that peanut oil which has been carefully handled has good keeping qualities, and as no noteworthy differences in properties appeared in the digestion experiments no further reference will be made to the source of the oil used.

Four different subjects assisted in the study of this fat, and the usual uniform and standardized conditions of conducting the work were maintained throughout the experiments. The results of the five tests are as follows:

Data of digestion experiments with peanut oil in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 30, subject J. N. F.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing peanut oil	1,918.0	1,037.0	47.8	340.6	481.2	11.4
Wheat biscuit	241.0	21.7	25.5	3.6	186.3	3.9
Fruit	1,002.0	847.7	4.0	5.0	142.3	3.0
Sugar	52.0				52.0	
Total food consumed	3,213.0	1,906.4	77.3	349.2	861.8	18.3
Feces	68.0		23.8	8.8	27.2	8.2
Amount utilized			53.5	340.4	834.6	10.1
Per cent utilized			69.2	97.5	96.8	55.2
Experiment No. 31, subject W. E. L.:						
Blancmange containing peanut oil	1,476.0	797.0	36.9	262.5	370.9	8.7
Wheat biscuit	26.0	2.3	2.8	0.4	20.1	0.4
Fruit	1,000.0	846.0	4.0	5.0	142.0	3.0
Sugar	143.0				143.0	
Total food consumed	2,645.0	1,645.3	43.7	267.9	676.0	12.1
Feces	32.0		11.4	6.4	10.5	3.7
Amount utilized			32.3	261.5	665.5	8.4
Per cent utilized			73.9	97.6	98.4	69.4
Experiment No. 32, subject W. A. D.:						
Blancmange containing peanut oil	1,883.0	1,022.4	47.2	332.6	469.7	11.1
Wheat biscuit	442.0	39.8	46.8	6.6	341.7	7.1
Fruit	819.0	692.9	3.3	4.1	116.3	2.4
Sugar	68.0				68.0	
Total food consumed	3,212.0	1,755.1	97.3	343.3	995.7	20.6
Feces	78.0		18.1	13.4	36.7	9.8
Amount utilized			79.2	329.9	959.0	10.8
Per cent utilized			81.4	96.1	96.3	52.4
Experiment No. 36, subject J. N. F.:						
Blancmange containing peanut oil	1,787.0	1,059.3	43.4	275.8	397.2	11.3
Wheat biscuit	224.0	20.2	23.7	3.4	173.1	3.6
Fruit	1,521.0	1,321.8	12.2	3.0	176.4	7.6
Sugar	40.0				40.0	
Total food consumed	3,572.0	2,401.3	79.3	282.2	786.7	22.5
Feces	78.0		18.1	17.7	31.5	10.7
Amount utilized			61.2	264.5	755.2	11.8
Per cent utilized			77.2	93.7	96.0	52.4
Experiment No. 37, subject J. V. C.:						
Blancmange containing peanut oil	1,704.0	1,010.7	41.6	262.9	377.8	11.0
Wheat biscuit	291.0	26.2	30.8	4.4	224.9	4.7
Fruit	1,442.0	1,253.1	11.5	2.9	167.3	7.2
Sugar	231.0				231.0	
Total food consumed	3,668.0	2,290.0	83.9	270.2	1,001.0	22.9
Feces	78.0		20.0	12.7	32.6	12.7
Amount utilized			63.9	257.5	968.4	10.2
Per cent utilized			76.2	95.3	96.7	44.5
Average food consumed per subject per day.	1,087.3	666.5	25.4	100.9	288.1	6.4

Summary of digestion experiments with peanut oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
30	J. N. F	69.2	97.5	96.8	55.2
31	W. E. L	73.9	97.6	98.4	69.4
32	W. A. D	81.4	96.1	96.3	52.4
36	J. N. F	77.2	93.7	96.0	52.4
37	J. V. C	76.2	95.3	96.7	44.5
	Average	75.6	96.0	96.8	54.8

Approximately 98 grams of peanut oil or 97 per cent of the total amount of fat in this diet was eaten per subject per day, and as the coefficient of availability, 96 per cent, implies, the fat was very completely assimilated. This value is increased somewhat by correcting for metabolic products, from which it is calculated that peanut oil is 98.3 per cent digested.

The protein and carbohydrate in the ration were also well utilized, for by way of comparison it has been found that in the total food of the ordinary mixed diet 92 per cent of the protein, 95 per cent of the fat, and 97 per cent of the carbohydrate are retained by the body.[1]

As the subjects reported no unusual effects as a result of eating this diet, and as no laxative effect was observed, it is apparent that peanut oil of good quality is a useful food, which can be eaten in the same quantities and can be as thoroughly digested as those fats and oils at present most commonly used in the diet.

COCONUT OIL.

Coconut oil is obtained from the fruit of the palm *Cocos nucifera.* In recent years it has become rather widely known and is assuming considerable importance as a culinary and table fat. It is used in the commercial baking trade more commonly than it is for household purposes and to some extent in the preparation of butter substitutes.

The digestibility of coconut oil has not been extensively studied. Bourot and Jean[2] carried on a series of experiments with subjects who received foods prepared first with natural butter and then with coconut butter. They concluded that the vegetable product was somewhat more thoroughly assimilated than was butter, the former being 98 per cent and the latter 96 per cent digested.

In a series of tests of 28 days' duration, divided into a fore period of 7 days, a 14-day experimental period, and an after period of 7 days, Von Gerlach[3] found that purified coconut oil, called "sanella," and true butter were both 97 per cent digested.

Lührig[4] reports a similar study in which different amounts of so-called coconut butter designed for use as a butter substitute were

[1] Connecticut Storr's Sta. Rpt. 1901, p. 245.
[2] Compt. Rend. Acad. Sci. [Paris], 123 (1896), No. 16, pp. 587–590.
[3] Ztschr. Phys. u. Diätet. Ther., 12 (1908–9), No. 2, pp. 102–110.
[4] Ztschr. Untersuch. Nahr. u. Genussmtl., 2 (1899), No. 8, pp. 622–632.

eaten in a simple mixed diet. In one of the tests 136 grams of the fat was consumed daily for three days, and in the second 90 grams per day for the same length of time. In the first test the fat was 97 per cent available and in the second, 96 per cent was assimilated.

Seven experiments are reported in this paper to compare the digestibility of coconut oil with that of other edible fats, and four experienced subjects assisted in the work. Under conditions customary in these tests, the data have been collected and are summarized in the following tables:

Data of digestion experiments with coconut oil in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 175, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing coconut oil	1,057.0	498.6	19.8	108.9	424.1	5.6
Wheat biscuit	656.0	59.1	69.5	9.8	507.1	10.5
Fruit	660.0	573.5	5.3	1.3	76.6	3.3
Sugar	125.0				125.0	
Total food consumed	2,498.0	1,131.2	94.6	120.0	1,132.8	19.4
Feces	98.0		28.4	8.5	52.4	8.7
Amount utilized			66.2	111.5	1,080.4	10.7
Per cent utilized			70.0	92.9	95.4	55.2
Experiment No. 176, subject R. L. S.:						
Blancmange containing coconut oil	1,518.0	716.0	28.5	156.4	609.1	8.0
Wheat biscuit	293.0	26.4	31.0	4.4	226.5	4.7
Fruit	1,335.0	1,160.1	10.7	2.7	154.8	6.7
Sugar	127.0				127.0	
Total food consumed	3,273.0	1,902.5	70.2	163.5	1,117.4	19.4
Feces	79.0		26.3	13.5	30.5	8.7
Amount utilized			43.9	150.0	1,086.9	10.7
Per cent utilized			62.5	91.7	97.3	55.2
Experiment No. 177, subject O. E. S.:						
Blancmange containing coconut oil	1,741.0	821.2	32.7	179.3	698.6	9.2
Wheat biscuit	98.0	8.8	10.4	1.5	75.7	1.6
Fruit	1,398.0	1,214.9	11.2	2.8	162.1	7.0
Sugar	37.0				37.0	
Total food consumed	3,274.0	2,044.9	54.3	183.6	973.4	17.8
Feces	77.0		25.0	8.3	36.6	7.1
Amount utilized			29.3	175.3	936.8	10.7
Per cent utilized			54.0	95.5	96.2	60.1
Experiment No. 178, subject R. F. T.:						
Blancmange containing coconut oil	1,460.0	688.7	27.4	150.4	585.8	7.7
Wheat biscuit	74.0	6.7	7.8	1.1	57.2	1.2
Fruit	1,317.0	1,144.5	10.5	2.6	152.8	6.6
Sugar	139.0				139.0	
Total food consumed	2,990.0	1,839.9	45.7	154.1	934.8	15.5
Feces	52.0		13.8	7.7	24.8	5.7
Amount utilized			31.9	146.4	910.0	9.8
Per cent utilized			69.8	95.0	97.3	63.2
Experiment No. 199, subject D. G. G.:						
Blancmange containing coconut oil	863.0	398.9	16.7	90.9	350.2	6.3
Wheat biscuit	525.0	47.2	55.7	7.9	405.8	8.4
Fruit	396.0	344.1	3.2	0.8	45.9	2.0
Sugar	162.0				162.0	
Total food consumed	1,946.0	790.2	75.6	99.6	963.9	16.7
Feces	94.0		28.8	11.9	44.8	8.5
Amount utilized			46.8	87.7	919.1	8.2
Per cent utilized			61.9	88.1	95.4	49.1

Data of digestion experiments with coconut oil in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 200, subject R. L. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing coconut oil	1,537.0	710.4	29.8	161.9	623.7	11.2
Wheat biscuit	366.0	32.9	38.8	5.5	282.9	5.9
Fruit	401.0	348.5	3.2	0.8	46.5	2.0
Sugar	155.0				155.0	
Total food consumed	2,459.0	1,091.8	71.8	168.2	1,108.1	19.1
Feces	103.0		33.4	15.8	42.2	11.6
Amount utilized			38.4	152.4	1,065.9	7.5
Per cent utilized			53.5	90.6	96.2	39.3
Experiment No. 201, subject O. E. S.:						
Blancmange containing coconut oil	1,841.0	850.9	35.7	193.9	747.1	13.4
Wheat biscuit	186.0	16.7	19.7	2.8	143.8	3.0
Fruit	1,713.0	1,488.6	13.7	3.4	198.7	8.6
Sugar	166.0				166.0	
Total food consumed	3,906.0	2,356.2	69.1	200.1	1,255.6	25.0
Feces	94.0		29.7	11.8	43.1	9.4
Amount utilized			39.4	188.3	1,212.5	15.6
Per cent utilized			57.0	94.1	96.6	62.4
Experiment No. 202, subject R. F. T.:						
Blancmange containing coconut oil	1,247.0	576.4	24.2	131.3	506.0	9.1
Wheat biscuit	62.0	5.6	6.6	0.9	47.9	1.0
Fruit	1,412.0	1,227.0	11.3	2.8	163.8	7.1
Sugar	112.0				112.0	
Total food consumed	2,833.0	1,809.0	42.1	135.0	829.7	17.2
Feces	37.0		10.5	6.1	16.2	4.2
Amount utilized			31.6	128.9	813.5	13.0
Per cent utilized			75.1	95.5	98.0	75.6
Experiment No. 222, subject D. G. G.:						
Blancmange containing coconut oil	1,625.0	744.2	30.5	238.7	600.2	11.4
Wheat biscuit	490.0	44.1	51.9	7.4	378.8	7.8
Fruit	965.0	838.6	7.7	1.9	112.0	4.8
Sugar	210.0				210.0	
Total food consumed	3,290.0	1,626.9	90.1	248.0	1,301.0	24.0
Feces	84.0		25.8	9.5	41.3	7.4
Amount utilized			64.3	238.5	1,259.7	16.6
Per cent utilized			71.4	96.2	96.8	69.2
Experiment No. 223, subject R. L. S.:						
Blancmange containing coconut oil	1,847.0	845.9	34.7	271.3	682.2	12.9
Wheat biscuit	290.0	26.1	30.7	4.4	224.2	4.6
Fruit	1,065.0	925.5	8.5	2.1	123.6	5.3
Sugar	96.0				96.0	
Total food consumed	3,298.0	1,797.5	73.9	277.8	1,126.0	22.8
Feces	93.0		29.0	17.5	36.7	9.8
Amount utilized			44.9	260.3	1,089.3	13.0
Per cent utilized			60.8	93.7	96.7	57.0
Experiment No. 224, subject O. E. S.:						
Blancmange containing coconut oil	2,678.0	1,226.5	50.2	393.4	989.1	18.8
Wheat biscuit	263.0	23.7	27.9	3.9	203.3	4.2
Fruit	1,449.0	1,259.2	11.6	2.9	168.1	7.2
Sugar	196.0				196.0	
Total food consumed	4,586.0	2,509.4	89.7	400.2	1,556.5	30.2
Feces	96.0		26.9	14.9	46.6	7.6
Amount utilized			62.8	385.3	1,509.9	22.6
Per cent utilized			70.0	96.3	97.0	74.8
Experiment No. 225, subject R. F. T.:						
Blancmange containing coconut oil	1,696.0	776.8	31.8	249.1	626.4	11.9
Wheat biscuit	221.0	19.9	23.4	3.3	170.8	3.6
Fruit	1,317.0	1,144.5	10.5	2.6	152.8	6.6
Sugar	130.0				130.0	
Total food consumed	3,364.0	1,941.2	65.7	255.0	1,080.0	22.1
Feces	78.0		20.8	18.7	29.5	9.0
Amount utilized			44.9	236.3	1,050.5	13.1
Per cent utilized			68.3	92.7	97.3	59.3
Average food consumed per subject per day	1,047.7	578.9	23.4	66.8	371.7	6.9

Summary of digestion experiments with coconut oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
175	D. G. G	70.0	92.9	95.4	55.2
176	R. L. S	62.5	91.7	97.3	55.2
177	O. E. S	54.0	95.5	96.2	60.1
178	R. F. T	69.8	95.0	97.3	63.2
199	D. G. G	61.9	88.1	95.4	49.1
200	R. L. S	53.5	90.6	96.2	39.3
201	O. E. S	57.0	94.1	96.6	62.4
202	R. F. T	75.1	95.5	98.0	75.6
222	D. G. G	71.4	96.2	96.8	69.2
223	R. L. S	60.8	93.7	96.7	57.0
224	O. E. S	70.0	96.3	97.0	71.8
225	R. F. T	68.3	92.7	97.3	59.3
	Average	64.5	93.5	96.7	60.0

On an average 64.6 grams of coconut oil was eaten daily and was well digested by the four subjects in these experiments, the average coefficient of digestibility being 93.5 per cent. The coefficient of availability is increased to 97.9 per cent by correcting for the metabolic products occurring in conjunction with the unutilized fat in the ether extract of the feces. In experiment No. 224, with subject O. E. S., a relatively large amount of the fat, 131 grams per day, was even more completely assimilated and, as evidenced by the report, produced no abnormal alimentary symptoms. In fact, no one of the subjects reported any laxative condition.

The protein and carbohydrates were 64.5 per cent and 96.7 per cent available to the body, values which compare favorably with the thoroughness of digestion of these constituents usually found in similar tests. It may be reasonably concluded on the basis of these results that coconut oil is suited to serve satisfactorily for food purposes.

SESAME OIL.

The seeds of the sesame plant (*Sesamum indicum*) yield when subjected to pressure an oil very similar in properties to cottonseed oil. Sesame oil is not produced in the United States for culinary purposes, although it is well known elsewhere and is imported to some extent for use by those who have become accustomed to its use in other countries.

Although tests of its digestibility have not been found on record, it is evident from a knowledge of oriental food habits and diets that sesame oil is well known as a useful food in the far eastern countries. The experiments herein reported were undertaken in order that the comparative results obtained with the vegetable fats might be as comprehensive as possible. The same methods were employed in these tests as with the other fats, and four subjects took part in the work. The experimental data are recorded below:

Data of digestion experiments with sesame oil in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 325, subject O. E. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing sesame oil	2,052.0	1,000.1	44.9	245.4	752.1	9.5
Wheat biscuit	394.0	35.4	41.8	5.9	304.6	6.3
Fruit	1,376.0	1,195.7	11.0	2.8	159.6	6.9
Sugar	141.0				141.0	
Total food consumed	3,963.0	2,231.2	97.7	254.1	1,357.3	22.7
Feces	88.0		30.9	12.0	36.4	8.7
Amount utilized			66.8	242.1	1,320.9	14.0
Per cent untilized			68.4	95.3	97.3	61.7
Experiment No. 330, subject H. F. B.:						
Blancmange containing sesame oil	2,146.0	975.6	44.2	299.1	818.3	8.8
Wheat biscuit	435.0	39.1	46.1	6.5	336.3	7.0
Fruit	1,046.0	909.0	8.4	2.1	121.3	5.2
Sugar	224.0				224.0	
Total food consumed	3,851.0	1,923.7	98.7	307.7	1,499.9	21.0
Feces	131.0		43.9	21.6	53.2	12.3
Amount utilized			54.8	286.1	1,446.7	8.7
Per cent utilized			55.5	93.0	96.5	41.4
Experiment No. 331, subject D. G. G.:						
Blancmange containing sesame oil	1,409.0	640.5	29.0	196.4	537.3	5.8
Wheat biscuit	594.0	53.4	63.0	8.9	459.2	9.5
Fruit	489.0	424.9	3.9	1.0	56.7	2.5
Sugar	136.0				136.0	
Total food consumed	2,628.0	1,118.8	95.9	206.3	1,189.2	17.8
Feces	134.0		41.6	16.2	65.7	10.5
Amount utilized			54.3	190.1	1,123.5	7.3
Per cent utilized			56.6	92.1	94.5	41.0
Experiment No. 332, subject R. L. S.:						
Blancmange containing sesame oil	2,028.0	921.9	41.8	282.7	773.3	8.3
Wheat biscuit	382.0	34.4	40.5	5.7	295.3	6.1
Fruit	601.0	522.3	4.8	1.2	69.7	3.0
Sugar	122.0				122.0	
Total food consumed	3,133.0	1,478.6	87.1	289.6	1,260.3	17.4
Feces	95.0		32.7	16.5	36.5	9.3
Amount utilized			54.4	273.1	1,223.8	8.1
Per cent utilized			62.5	94.3	97.1	46.6
Experiment No. 333, subject O. E. S.:						
Blancmange containing sesame oil	2,291.0	1,041.5	47.2	319.4	873.5	9.4
Wheat biscuit	411.0	37.0	43.6	6.1	317.7	6.6
Fruit	1,274.0	1,107.1	10.2	2.5	147.8	6.4
Sugar	320.0				320.0	
Total food consumed	4,296.0	2,185.6	101.0	328.0	1,659.0	22.4
Feces	117.0		36.6	18.2	51.1	11.1
Amount utilized			64.4	309.8	1,607.9	11.3
Per cent utilized			63.8	94.5	96.9	50.4
Average food consumed per subject per day	1,191.4	595.9	32.0	92.4	464.4	6.7

Summary of digestion experiments with sesame oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
325	O. E. S.	68.4	95.3	97.3	61.7
330	H. F. B.	55.5	93.0	96.5	41.4
331	D. G. G.	56.6	92.1	94.5	41.0
332	R. L. S.	62.5	94.3	97.1	46.6
333	O. E. S.	63.8	94.5	96.9	50.4
	Average	61.4	93.8	96.5	48.2

The results of these tests indicate that sesame oil compares favorably with the preceding vegetable fats as regards thoroughness of digestion. Of the total fat in the diet, 93.8 per cent was available while 61.4 and 96.5 per cent of the protein and carbohydrates were utilized by the body. The revised value for the digestibility of sesame oil alone, allowing for metabolic products, is 98 per cent.

The amount of sesame oil eaten per subject daily was 90 grams, and in one case, experiment No. 333 with subject O. E. S., 106 grams of the fat was consumed daily without apparent physiological aversion, and when eaten in amounts not exceeding 106 grams daily it apparently produces no laxative effect. Sesame oil, therefore, may be considered a useful food.

COCOA BUTTER.

Cocoa butter is obtained as a by-product of the manufacture of cocoa from the cocoa bean, the fruit of *Theobroma cacao*. The product is a hard, yellowish fat of the odor of cocoa and has an agreeable taste and rather low melting point. Compared with other vegetable fats cocoa butter is relatively expensive and for this reason no doubt it is little used as such in the preparation of food products, although large quantities of cocoa butter are eaten as an intimate constituent of chocolate.

As no noteworthy records of physiological tests of this fat have been found in the review of the literature it is hoped that the results of these experiments may be of special value. The fat, already used in quantity in the making of confectionery, may assume importance in other ways when it is possible to have a definite opinion regarding the dietetic value of chocolate (retaining the cocoa fat) and cocoa (from which fat has been removed). The experimental data are recorded in the following table:

Data of digestion experiments with cocoa butter in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 167, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing cocoa butter..	1,315.0	594.3	23.0	180.8	511.1	5.8
Wheat biscuit	497.0	44.7	52.7	7.4	384.2	8.0
Fruit	611.0	531.0	4.9	1.2	70.9	3.0
Sugar	191.0	....	....	....	191.0	....
Total food consumed	2,614.0	1,170.0	80.6	189.4	1,157.2	16.8
Feces	112.0	....	30.2	13.3	57.8	10.7
Amount utilized	....	....	50.4	176.1	1,099.4	6.1
Per cent utilized	....	....	62.5	93.0	95.0	36.3
Experiment No. 168, subject R. L. S.:						
Blancmange containing cocoa butter..	1,310.0	592.0	22.9	180.1	509.2	5.8
Wheat biscuit	291.0	26.2	30.8	4.4	224.9	4.7
Fruit	1,232.0	1,070.6	9.8	2.5	142.9	6.2
Sugar	63.0	....	....	....	63.0	....
Total food consumed	2,896.0	1,688.8	63.5	187.0	940.0	16.7
Feces	84.0	....	25.6	19.2	30.5	8.7
Amount utilized	....	....	37.9	167.8	909.5	8.0
Per cent utilized	....	....	59.7	89.7	96.8	47.9

Data of digestion experiments with cocoa butter in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 169, subject O. E. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing cocoa butter..	1,465.0	662.0	25.6	201.4	569.5	6.5
Wheat biscuit	83.0	7.5	8.8	1.2	64.2	1.3
Fruit	1,392.0	1,209.6	11.1	2.8	161.5	7.0
Sugar	68.0	....	....	....	68.0	....
Total food consumed	3,008.0	1,879.1	45.5	205.4	863.2	14.8
Feces	68.0	....	18.9	16.3	26.2	6.6
Amount utilized	....	....	26.6	189.1	837.0	8.2
Per cent utilized	....	....	58.5	92.1	97.0	55.4
Experiment No. 170, subject R. F. T.:						
Blancmange containing cocoa butter..	1,391.0	628.6	24.3	191.3	540.7	6.1
Wheat biscuit	71.0	6.4	7.5	1.1	54.9	1.1
Fruit	1,459.0	1,267.9	11.7	2.9	169.2	7.3
Sugar	141.0	....	....	....	141.0	....
Total food consumed	3,062.0	1,902.9	43.5	195.3	905.8	14.5
Feces	61.0	....	13.8	11.4	29.8	6.0
Amount utilized	....	....	29.7	183.9	876.0	8.5
Per cent utilized	....	....	68.3	94.2	96.7	58.6
Experiment No. 191, subject D. G. G.:						
Blancmange containing cocoa butter..	582.0	261.7	10.4	80.6	225.9	3.4
Wheat biscuit	509.0	45.8	54.0	7.6	393.5	8.1
Fruit	432.0	375.4	3.4	0.9	50.1	2.2
Sugar	189.0	....	....	....	189.0	....
Total food consumed	1,712.0	682.9	67.8	89.1	858.5	13.7
Feces	69.0	....	21.6	9.4	31.2	6.8
Amount utilized	....	....	46.2	79.7	827.3	6.9
Per cent utilized	....	....	68.1	89.5	96.4	50.4
Experiment No. 192, subject R. L. S.:						
Blancmange containing cocoa butter..	812.0	365.2	14.5	112.4	315.1	4.8
Wheat biscuit	564.0	50.7	59.8	8.5	436.0	9.0
Fruit	1,372.0	1,192.3	11.0	2.7	159.1	6.9
Sugar	123.0	....	....	....	123.0	....
Total food consumed	2,871.0	1,608.2	85.3	123.6	1,033.2	20.7
Feces	114.0	....	31.7	25.8	41.5	15.0
Amount utilized	....	....	53.6	97.8	991.7	5.7
Per cent utilized	....	....	62.8	79.1	96.0	27.5
Experiment No. 193, subject O. E. S.:						
Blancmange containing cocoa butter..	1,230.0	553.1	22.0	170.2	477.3	7.4
Wheat biscuit	127.0	11.4	13.5	1.9	98.2	2.0
Fruit	1,482.0	1,287.9	11.8	3.0	171.9	7.4
Sugar	198.0	....	....	....	198.0	....
Total food consumed	3,037.0	1,852.4	47.3	175.1	945.4	16.8
Feces	40.0	....	11.9	7.9	15.9	4.3
Amount utilized	....	....	35.4	167.2	929.5	12.5
Per cent utilized	....	....	74.8	95.5	98.3	74.4
Experiment No. 194, subject R. F. T.:						
Blancmange containing cocoa butter..	807.0	362.9	14.4	111.7	313.2	4.8
Wheat biscuit	93.0	8.4	9.8	1.4	71.9	1.5
Fruit	1,262.0	1,096.7	10.1	2.5	146.4	6.3
Sugar	163.0	....	....	....	163.0	....
Total food consumed	2,325.0	1,468.0	34.3	115.6	694.5	12.6
Feces	36.0	....	9 7	8.6	13.4	4.3
Amount utilized	....	....	24.6	107 0	681.1	8.3
Per cent utilized	....	....	71.7	92.6	98.1	65.9
Experiment No. 235, subject D. G. G.:						
Blancmange containing cocoa butter..	1,571.0	702.4	29.0	246.2	582.3	11.1
Wheat biscuit	439.0	39.5	46.5	6.6	339.4	7.0
Fruit	337.0	292.8	2.7	0.7	39.1	1.7
Sugar	114.0	....	....	....	114.0	....
Total food consumed	2,461.0	1,034.7	78.2	253.5	1,074.8	19.8
Feces	146.0	....	34.9	33.6	64.1	13.4
Amount utilized	....	....	43.3	219.9	1,010.7	6.4
Per cent utilized	....	....	55.4	86.7	94.0	32.3

Data of digestion experiments with cocoa butter in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 236, subject R. L. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing cocoa butter..	2,020.0	903.2	37.2	316.5	748.8	14.3
Wheat biscuit..........................	433.0	39.0	45.9	6.5	334.7	6.9
Fruit..................................	716.0	622.2	5.7	1.4	83.1	3.6
Sugar..................................	84.0	....	....	....	84.0	....
Total food consumed............	3,253.0	1,564.4	88.8	324.4	1,250.6	24.8
Feces..................................	129.0	....	33.5	32.9	49.5	13.1
Amount utilized....................	....	....	55.3	291.5	1,201.1	11.7
Per cent utilized..................	....	....	62.3	89.9	96.0	47.2
Experiment No. 237, subject O. E. S.:						
Blancmange containing cocoa butter..	2,649.0	1,184.4	48.7	415.1	982.0	18.8
Wheat biscuit..........................	463.0	41.7	49.1	6.9	357.9	7.4
Fruit..................................	1,280.0	1,112.3	10.2	2.6	148.5	6.4
Sugar..................................	228.0	....	....	....	228.0	....
Total food consumed............	4,620.0	2,338.4	108.0	424.6	1,716.4	32.6
Feces..................................	195.0	....	37.7	72.6	70.2	14.5
Amount utilized....................	....	....	70.3	352.0	1,646.2	18.1
Per cent utilized..................	....	....	65.1	82.9	95.9	55.5
Average food consumed per subject per day.	965.4	520.9	22.5	69.2	346.6	6.2

Summary of digestion experiments with cocoa butter in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
167.......	D. G. G............	62.5	93.0	95.0	36.3
168.......	R. L. S............	59.7	89.7	96.8	47.9
169.......	O. E. S............	58.5	92.1	97.0	55.4
170.......	R. F. T............	68.3	94.2	96.7	58.6
191.......	D. G. G............	68.1	89.5	96.4	50.4
192.......	R. L. S............	62.8	79.1	96.0	27.5
193.......	O. E. S............	74.8	95.5	98.3	74.4
194.......	R. F. T............	71.7	92.6	98.1	65.9
235.......	D. G. G............	55.4	86.7	94.0	32.3
236.......	R. L. S............	62.3	89.9	96.0	47.2
237.......	O. E. S............	65.1	82.9	95.9	55.5
	Average............	64.5	89.6	96.4	50.1

On an average the coefficient of digestibility of this fat was low, the corrected value being 94.9 per cent. It will be recalled that the food (blancmange) used as a vehicle for fat in such experiments as this is eaten ad libitum from a weighed amount, provided the amount being such that the subjects would naturally be inclined to eat a quantity which would supply in the neighborhood of 100 grams of fat per day. The fat-carrying blancmange was evidently not relished in this test as it was in the others here reported, for the amount eaten was only enough to supply 51 grams of cocoa fat per man per day during the first eight experiments. This quantity did not cause any decided digestive disturbance so far as was noted. The subjects reported a "loss of appetite," but in all other respects considered that their physical condition had been normal. In later tests, experiments Nos. 235 to 237, the subjects were urged to eat more of the blancmange containing the cocoa butter. As a result of eating the larger quantities, an average of 109 grams per day (82 grams for D. G. G., 106 grams for R. L. S., and 138 grams for O. E. S.), undesirable physiological derangements were experienced. The effects were so pronounced that subject D. G. G. discontinued the diet at the end of the seventh meal, but subjects R. L. S. and O. E. S. completed the full nine-meal period. "Loss of appetite," "headache," "loss of ambition," "nausea," and "sleeplessness" were the conditions reported, which indicate that cocoa butter in quantity had an effect not noted of the other vegetable fats studied. Though the exact limit of tolerance has not been determined, to judge by the experiments made in this laboratory, the maximum amount of cocoa butter that can be consumed daily without decidedly unpleasant effects lies between 51 grams and 109 grams.

The digestibility of the carbohydrate, 96.4 per cent, and of the protein, 64.5 per cent, agrees fairly closely with the average availability of these constituents, and would seem to be uninfluenced by the digestibility of the fat.

It will be noted on reference to the table that the feces contained comparatively large quantities of fat during the last three experiments. In experiment No. 237 as much as 37 per cent of the weight of the air-dried feces was fat, and an odor suggesting that of cocoa butter could be clearly detected. In view of the unsatisfactory utilization of this fat and the accompanying physiological disturbances, the continued daily use of cocoa butter in large amounts would appear questionable, and, as a matter of fact, it does not seem to be so used.

CONCLUSIONS.

(1) With allowance for metabolic products, the coefficients of digestibility have been found to be for olive oil, 97.8; for cottonseed oil, 97.8; for peanut oil, 98.3; for coconut oil, 97.9; for sesame oil, 98; and for cocoa butter, 94.9 per cent. These values indicate that the vegetable fats studied, with the exception of cocoa butter, have for all practical purposes the same digestibility and are utilized as completely as the animal fats.

(2) The melting points of these fats are considerably lower than body temperature (37° C.) and in accordance with the theory that fats of low melting points are more thoroughly digested than the harder fats, it has been found that the vegetable fats studied, with the exception of cocoa butter, are utilized practically completely by the body.

(3) The average amounts of fat eaten per subject daily were 73 grams of olive, 86 grams of cotton seed, 98 grams of peanut, 64 grams of coconut, and 90 grams of sesame oils. Moreover, as much as 103, 125, 113, 131, and 106 grams of these fats, respectively, were eaten

by one of the subjects for a 3-day period without any physiological disturbance. In the first eight experiments with cocoa butter, in which an average of only 51 grams of this fat was eaten daily, no abnormal conditions were noted and the apparent digestibility of fat was 90.7 per cent. In those experiments, however, in which 82 to 138 grams of cocoa butter were consumed daily and 86.5 per cent utilized, a decided laxative effect was noted. Accordingly, it may be concluded that the limit of tolerance is less for cocoa butter than for the other fats studied.

(4) The evidence collected in these experiments affords additional proof that the digestibility of protein and carbohydrate contained in the different fat diets was not materially affected by the nature of the fat or by the amount eaten.

(5) The total energy values (heats of combustion) of the material consumed on the average per man per day were 2,700 calories for olive oil, 2,955 calories for cottonseed oil, 2,290 calories for peanut oil, 2,305 calories for coconut oil, 2,975 calories for sesame oil, and 2,215 calories for cocoa butter. While no attention was given to the energy value of these diets, it is interesting to note that the amount of food consumed contained sufficient energy value except for those engaged in muscular activities. The percentage of energy actually available to the body was 93.9 for olive oil, 93.4 for cottonseed oil, 93.9 for peanut oil, 93.1 for coconut oil, 92.8 for sesame oil, and 91.9 for cocoa butter. These values imply, on comparison with the percentage of energy available from the ordinary mixed diet, which is 91 per cent,[1] that normal conditions existed during the digestion experiments and that protein, fat, and carbohydrates were as thoroughly digested as is usually the case.

(6) Judging from the results of the investigation as a whole, it is reasonable to conclude that olive, cottonseed, peanut, coconut, and sesame oils are very completely and readily available to the body and that they may, like the animal fats, be satisfactorily used for food purposes.

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[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 136 (1903), p. 113.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATIVE TO FOOD AND NUTRITION.

AVAILABLE FOR FREE DISTRIBUTION.

Meats: Composition and Cooking. By Chas. D. Woods. Pp. 31, figs. 4. 1904. (Farmers' Bulletin 34.)

The Use of Milk as Food. By R. D. Milner. Pp. 44. 1911. (Farmers' Bulletin 363.)

Care of Food in the Home. By Mrs. Mary Hinman Abel. Pp. 46, figs. 2. 1910. (Farmers' Bulletin 275.)

Economical Use of Meat in the Home. By C. F. Langworthy and Caroline L. Hunt. Pp. 30. 1910. (Farmers' Bulletin 391.)

Cheese and Its Economical Uses in the Diet. By C. F. Langworthy and Caroline L. Hunt. Pp. 40. 1912. (Farmers' Bulletin 487.)

Mutton and Its Value in the Diet. By C. F. Langworthy and Caroline L. Hunt. Pp. 32, figs. 2. 1913. (Farmers' Bulletin 526.)

The Detection of Phytosterol in Mixtures of Animal and Vegetable Fats. By R. H. Kerr. Pp. 4. 1913. (Bureau of Animal Industry Circular 212.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS.

Experiments on Losses in Cooking Meat, 1900–1903. By H. S. Grindley, D. Sc., and Timothy Mojonnier, M. S. Pp. 95, tables 82. 1904. (Office of Experiment Stations Bulletin 141.) Price, 5 cents.

Studies on the Influence of Cooking upon the Nutritive Value of Meats at the University of Illinois, 1903–1904. By H. S. Grindley, Sc. D., and A. D. Emmett, A. M. Pp. 230, tables 136. 1905. (Office of Experiment Stations Bulletin 162.) Price, 20 cents.

Studies of the Effect of Different Methods of Cooking upon the Thoroughness and Ease of Digestion of Meats at the University of Illinois. By H. S. Grindley, D. Sc., Timothy Mojonnier, M. S., and Horace C. Porter, Ph. D. Pp. 100, tables 38. 1907. (Office of Experiment Stations Bulletin 193.) Price, 15 cents.

Food Customs and Diet in American Homes. By C. F. Langworthy, Ph. D. Pp. 32. 1911. (Office of Experiment Stations Circular 110.) Price, 5 cents.

Digestibility of Some Animal Fats. By C. F. Langworthy and A. D. Holmes. Pp. 23. 1915. (Department Bulletin 310.) Price, 5 cents.

Digestibility of Very Young Veal. By C. F. Langworthy and A. D. Holmes. Pp. 577–588. 1916. (Journal of Agricultural Research, 6 (1916), No. 16.) Price 5 cents.

Digestibility of Hard Palates of Cattle. By C. F. Langworthy and A. D. Holmes. Pp. 641–648. 1916. (Journal of Agricultural Research, 6 (1916), No. 17.) Price 5 cents.

Fats and Their Economical Use in the Home. By A. D. Holmes and H. L. Lang. Pp. 27. 1916. (Department Bulletin 469.) Price 5 cents.

Studies on the Digestibility of the Grain Sorghums. By C. F. Langworthy and A. D. Holmes. Pp. 31. 1916. (Department Bulletin 470.) Price 5 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 506

Contribution from the Forest Service
H. S. GRAVES, Forester

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PRODUCTION OF LUMBER, LATH, AND SHINGLES IN 1915 AND LUMBER IN 1914.

By J. C. Nellis, *Forest Examiner.*

CONTENTS.

INTRODUCTION.

Detailed statistics on the 1915 production of lumber, lath, and shingles are given in this bulletin. Preliminary statements issued in the spring of 1916 summarized the data for the early information of the lumber trade. There is now presented a permanent and complete record of the 1915 lumber cut, with comparisons of the production in that year with previous years.

Note.—Acknowledgment for assistance in compiling the bulletin is due R. S. Kellogg, secretary National Lumber Manufacturers' Association; A. B. Strough, New York Conservation Commission; P. T. Coolidge, New Jersey Department of Conservation and Development; and the following members of the Forest Service: F. H. Smith, A. H. Pierson, C. M. Granger, C. W. Gould, C. A. Kupfer, H. N. Knowlton, and A. L. Brower.

This bulletin is one of a series issued annually, covering the years 1905 to 1915, inclusive, with the exception of 1914. Data for that year were compiled by the Bureau of the Census in cooperation with the Forest Service, and the totals announced early in 1916. A detailed summary of the 1914 lumber cut is given in the appendix. The 1913 lumber census was conducted by the Forest Service in cooperation with the Bureau of Crop Estimates, and the results published as United States Department of Agriculture Bulletin No. 232. The work for the other years mentioned above, except 1905, was done by the Bureau of the Census in cooperation with the Forest Service, and the results issued as a Forest Service bulletin for 1906 and as Census bulletins for 1907 to 1912, inclusive. The Forest Service secured the data and issued the report for 1905. Statistics on lumber cut were also secured by the Census for the quinquennial year 1904 and decennial years 1899, 1889, etc., back to 1850. The detailed results appear in the Census reports for those years.

The Bureau of the Census discontinued annual lumber-cut statistics after 1912 because of lack of funds, but the quinquennial census of manufactures covering 1914 included the lumber industry, with the exception of custom and very small mills.

In securing figures for lumber production in 1915 the National Lumber Manufacturers' Association agreed to cooperate financially, provided figures on the total cut would be issued before May 1, 1916. This condition was fulfilled. It was necessary to rely chiefly upon correspondence in securing reports from the mills, and in this work the national association and regional associations[1] also cooperated heartily. The New York Conservation Commission and the New Jersey Department of Conservation and Development furnished the statistics for those States. All other States east of the Rocky Mountains were handled by the Office of Industrial Investigations, Forest Service, Washington, D. C., while the Western States were taken care of by the Forest Service district products offices at Albuquerque, Denver, Missoula, Ogden, Portland, and San Francisco. The Pennsylvania Department of Forestry, which annually compiles data on stumpage cut, assisted in completing returns from Pennsylvania mills. The Office of Industrial Investigations was the clearing house for all statistics, issued the preliminary statements giving figures for the whole country, and prepared this bulletin.

[1] Georgia-Florida Sawmill Association.
Hardwood Manufacturers' Association.
Michigan Hardwood Manufacturers' Association.
Mississippi Pine Association.
North Carolina Pine Association.
Northern Hemlock & Hardwood Manufacturers' Association.
Northern Pine Association.
Southern Cypress Association.
Southern Pine Association.
West Coast Lumbermen's Association.
Western Pine Manufacturers' Association.
Yellow Pine Exchange (Alexandria, La.)

Table 1 shows the reported lumber cut for each year since 1899 for which data have been compiled, and the number of active mills reporting each year. In connection with the recent study of the lumber industry by the Forest Service, the total cut in most of the years listed has been estimated, and these figures also are given. The statistics for different years are not exactly comparable, because of the varying number of small mills which reported. For 1899 and 1909 the enumeration was complete, special agents of the Bureau of the Census canvassing the mills in connection with the decennial censuses. The figures for other years were secured mostly by correspondence. Further, reports from mills cutting less than 50,000 feet were omitted from the statistics for 1904, 1910, and later, and the censuses of 1904 and 1914 excluded custom mills, while for the other years previous to 1910, except 1904, all mills for which reports were secured are included in the statistics.

The lumber cut of 1915 was influenced by a large surplus carried over from 1914 and by the restricted markets brought about by the European war. Domestic lines of trade were kept at fair volume through the year, and this created a fair domestic demand for lumber. However, the lumber industry failed to share greatly in war orders, because of lack of shipping. A greatly increased amount of thick walnut lumber was cut for gunstocks. Dimension stock in ash for aeroplanes, and ash, hickory, and oak for vehicles and tools, probably figured largely in war orders, but such material does not show in this bulletin, because it would not be reported as lumber. The latter part of 1915 witnessed a remarkable revival of domestic lumber buying, largely for building purposes, but it occurred too late in the year to keep the probable total cut from being less than for any census year since 1899.

TABLE 1.—*Number of active sawmills reporting, quantity of lumber reported, and estimated total cut: 1899–1915.*

Year.	Number of active sawmills reporting.	Quantity of lumber.		Year.	Number of active sawmills reporting.	Quantity of lumber.	
		Reported, M ft. b. m.	Estimated total cut, M ft. b. m.			Reported, M ft. b. m.	Estimated total cut, M ft. b. m.
1899	31,833	35,084,166	....	1910[3]	[2] 31,934	40,018,282	44,500,000
1904[1]	[2] 18,277	34,135,139	43,000,000	1911[3]	[2] 28,107	37,003,207	48,000,000
1905	11,666	30,502,961	43,500,000	1912	[2] 29,005	39,158,414	45,000,000
1906	22,398	37,550,736	46,000,000	1913	[2] 21,668	38,387,009	44,000,000
1907[3]	28,850	40,256,154	46,000,000	1914[1]	[2] 27,506	37,346,023	40,500,000
1908[3]	31,231	33,224,369	42,000,000	1915	[2] 16,815	31,241,734	38,000,000
1909	[4] 46,584	44,509,761	44,509,761				

[1] Custom mills excluded.
[2] Mills cutting under 50 M feet excluded.
[3] Including mills which manufacture lath and shingles exclusively (1,500 estimated).
[4] Includes 4,543 mills cutting less than 50 M feet, and all cooperage, veneer, millwork, box, furniture, and other factories cutting any lumber at all in 1909.

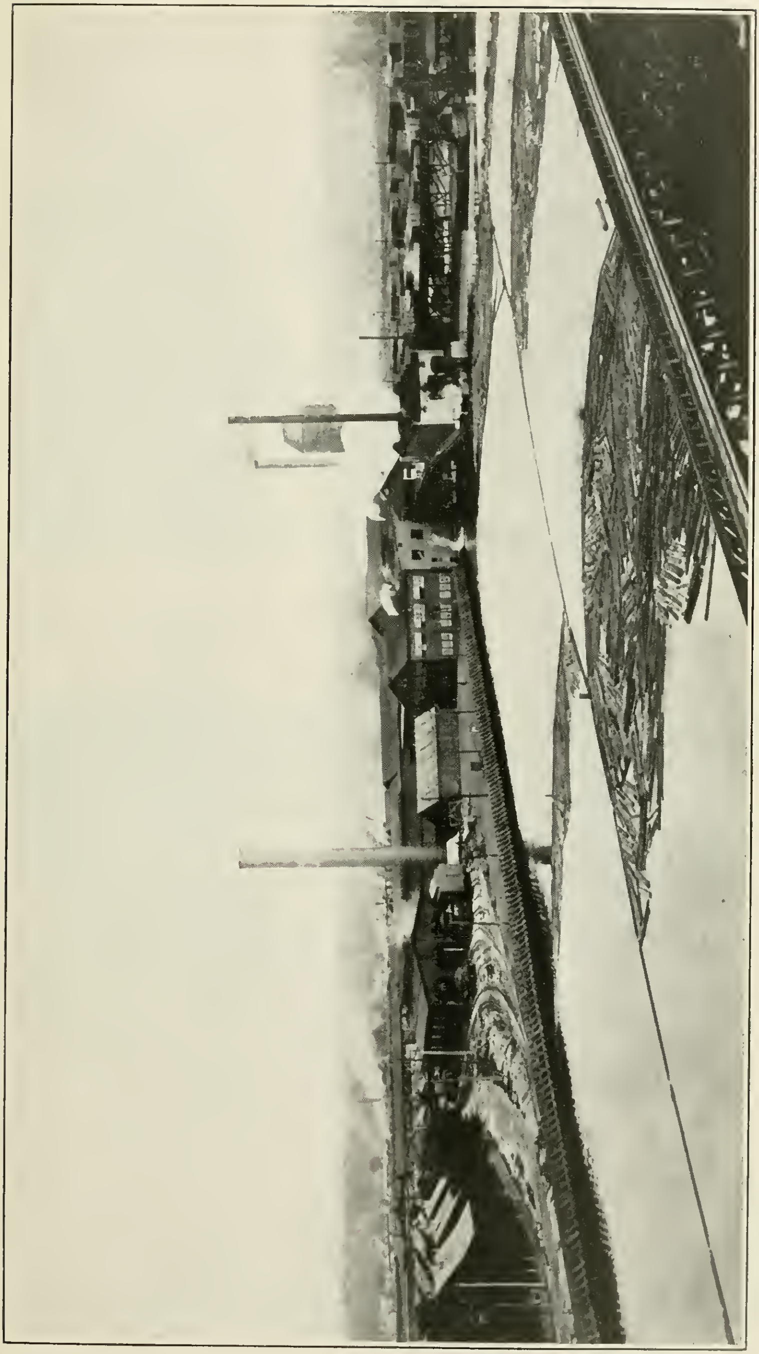
METHOD OF COMPILATION.

The collection of reports, mostly by mail, was continued until the last of April, 1916. At that time, with reports from 16,815 mills of an aggregate cut in 1915 of 31,241,734,000 board feet as a basis, the Forest Service computed the total cut of lumber in 1915 to be 37,011,-656,000 board feet by 29,951 mills assumed to have been active. Although these figures were arrived at by a process of computation based on known facts, it is possible that the results are too conservative. In all, there may have been 33,000 or 34,000 mills active. If this was the case, practically all of the additional mills were of the smallest class, cutting on an average less than 200,000 board feet each. The total cut of these mills might have amounted to nearly a billion feet, and it is therefore possible that the grand total lumber cut in 1915 was 38,000,000,000 feet.

As reports from the big mills came in, the Forest Service issued a cumulative series of comparisons of the 1915 and 1914 production of identical mills cutting 5,000,000 board feet or over in either year, including mills idle one year but not mills cutting out. Since such mills cut 65 per cent of the total lumber production, data on their operations are significant in showing the trend of production. The final comparison resulted in the following figures representing per cents of increase or decrease in 1915 as compared with 1914 in respective States, in the cut of the largest mills:

State.	Number of mills.	Increase or decrease.	State.	Number of mills.	Increase or decrease.
		Per cent.			*Per cent.*
Arkansas	72	+ 4	Pennsylvania	20	+ 8
Oklahoma	5	+21	New York	9	− 3
Texas	69	+ 2	New Hampshire and Massachusetts	7	+29
Louisiana	168	− 3	Maine	40	+ 1
Mississippi	102	− 7	Central and Northern States	390	−14
Alabama	49	− 1	Washington	149	+ 5
Georgia	37	− 1	Oregon	64	−10
Florida	65	− 1	California	51	−10
South Carolina	37	+17	Idaho	25	− 5
North Carolina	80	− 1	Montana	12	0
Virginia	35	0	Colorado and South Dakota	3	− 4
Southern pine States	719	− 3	Arizona	4	− 3
West Virginia	65	− 9	New Mexico	6	+ 3
Kentucky	19	−10	Western States	313	− 2
Tennessee	29	−24	All above States	1,422	− 5
Missouri	12	−28			
Minnesota	37	−21			
Wisconsin	75	−13			
Michigan	77	−20			

Results were compiled according to the classes of mills indicated on page 7. Eight hundred and twenty-one class 5 mills reported a total cut of 20,225,449,000 feet. About 100 of these cut somewhat less than 10,000,000 feet in 1914, and so were class 4 that year. How-



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A CLASS 5 MILL.

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FIG. 1.—A CLASS 3 MILL.

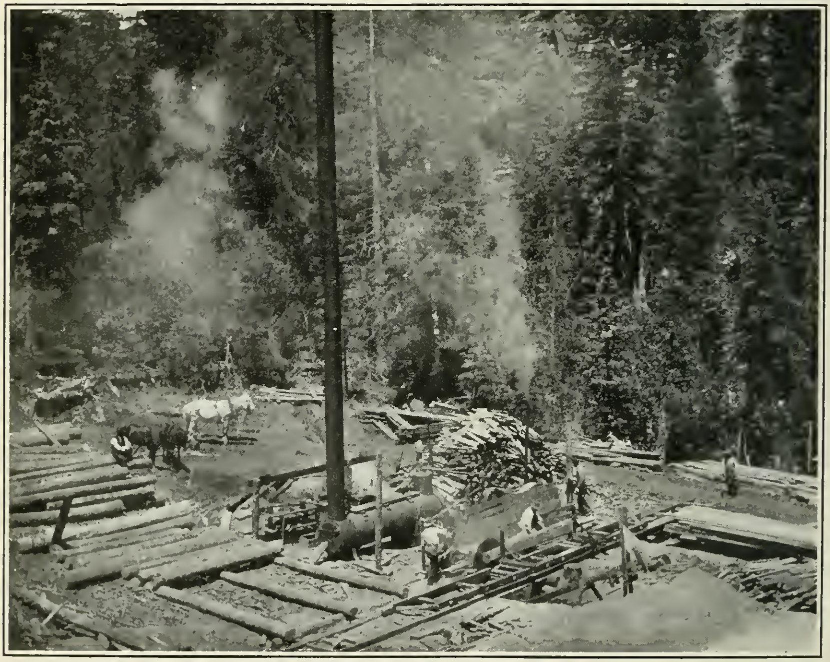

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FIG. 2.—A CLASS 1 MILL.

ever, of about 300 mills that were class 5 in previous years, 100 were idle in 1915, 150 cut less than 10,000,000 feet, and the rest were out of business. In addition to the class 5 mills reporting, it is estimated that 25 more such mills were active in 1915. On the basis in some cases of estimates and in others of the average cut of the mills reporting, the entire number of class 5 mills active in 1915—846—probably cut 20,669,746,000 feet.

Four hundred and twenty-two class 4 mills reported their 1915 cut as 3,000,522,000 feet. The number of such mills was much smaller than in previous years, owing mainly to the fact that a great many mills which were class 4 in 1914 dropped to lower classes or were idle in 1915. It is estimated that 453 class 4 mills operated in 1915. On the basis of the average production of those reporting, the 453 had a total cut of probably 3,224,448,000 feet.

Two thousand two hundred and nineteen class 3 mills reported a 1915 production of 4,368,641,000 feet. On the basis of the Census figures for 1914, and the increases or decreases in production by States shown above, it is estimated that 3,191 class 3 mills operated in 1915. On the basis of the average cut of those reporting, the total cut of this class is estimated at 6,201,864,000 feet.

Two thousand three hundred and thirty-one class 2 mills reported a cut of 1,578,729,000 feet. In the same way as for class 3, it is estimated that 4,198 class 2 mills were active in 1914 and produced a total of 2,941,264,000 feet.

Class 1 mills to the number of 11,022 reported their 1915 production as 2,068,393,000 feet. In poor business years a great many small mills do not operate and curtailment by larger mills drops many into this class. With consideration also for the number of class 1 mills reported active in 1914 by the Bureau of the Census, the number of class 1 mills in previous years, and the per cents of increase or decrease in production, it is estimated that 21,263 mills of this class were active in 1915. On the basis of the average cut of those reporting, the total cut of the class was 3,974,334,000 feet.

In this manner the probable total cut of 37,011,656,000 feet was computed. It is believed that either a report was secured or an estimate made for every class 5 mill active in 1915. The number of active class 4 mills is placed as high as is warranted by the data at hand, while in the case of classes 3 and 2 the estimate of the total number operating is as high as the facts warrant. While Table 2 shows that the estimated number of class 1 mills active in 1915 forms a little greater proportion of all mills than does class 1 in previous years, it is possible that a few thousand more class 1 mills may have operated than are shown, but in any event it seems improbable that the total cut of lumber in 1915 was more than 38,000,000,000 feet.

PRODUCTION BY CLASSES OF MILLS.

Table 2 (page 7) shows the production by classes of sawmills for the years for which such data have been compiled. Mills having an annual cut of less than 50,000 feet have not been considered for the years since 1909. The 1909 total figure in Table 2 is thus reduced, and so is slightly less than the corresponding figure in Table 1. Reports from such mills would probably not have increased the total production by more than one-half of 1 per cent. Table 2 and figure 1 show that the large sawmills furnish most of the supply of lumber, and also how a nearly complete lumber census can be made by persistent efforts to get reports from mills cutting 1,000,000 feet and over. The 1915 lumber census was conducted in this manner.

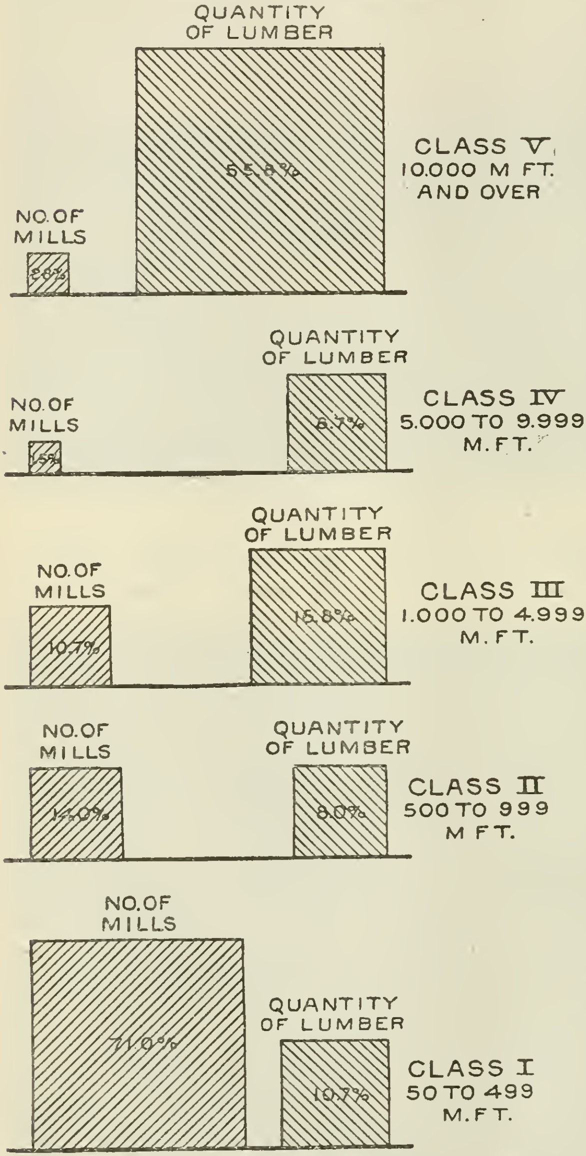


FIG. 1.—Computed total lumber production in 1915, by classes of mills.

Figure 1 shows graphically the number of mills and the production of each class. The small number of mills in class 5, which cut 55.8 per cent of the total, is very significant when compared with the large number of mills in class 1, which cut only 10.7 per cent of the total.

TABLE 2.—*Reported production of lumber 1909, 1912, 1913, 1914, and 1915, computed totals, by classes of mills.*

Class.	Year.	Mills.		Quantity reported.	
		Number reporting.	Per cent.	M feet b. m.	Per cent.
Class 5: 10,000 M and over per year	1909	888	2.11	19,126,223	43.09
	1912	926	3.19	21,259,274	54.29
	1913	974	4.50	23,211,667	60.47
	1914	867	3.15	20,934,446	56.06
	[1] 1915	846	2.82	20,669,746	55.84
Class 4: 5,000 M to 9,999 M per year	1909	783	1.86	5,291,606	11.92
	1912	608	2.10	4,311,063	11.01
	1913	740	3.41	4,303,122	11.21
	1914	547	1.99	3,910,370	10.47
	[1] 1915	453	1.51	3,224,448	8.71
Class 3: 1,000 M to 4,999 M per year	1909	5,443	12.95	10,068,592	22.69
	1912	3,747	12.92	7,009,608	17.90
	1913	3,265	15.07	6,319,753	16.46
	1914	3,291	11.97	6,078,730	16.28
	[1] 1915	3,191	10.65	6,201,864	16.76
Class 2: 500 M to 999 M per year	1909	6,468	15.39	4,315,636	9.72
	1912	4,420	15.24	2,951,068	7.54
	1913	3,148	14.53	2,049,642	5.34
	1914	4,261	15.49	2,780,184	7.44
	[1] 1915	4,198	14.02	2,941,264	7.95
Class 1: 50 M to 499 M per year	1909	28,459	67.69	5,582,738	12.58
	1912	19,304	66.55	3,627,401	9.26
	1913	13,541	62.49	2,502,825	6.52
	1914	18,540	67.40	3,642,293	9.75
	[1] 1915	21,263	70.99	3,974,334	10.74
All classes	[2] 1909	42,041	100.00	44,384,795	100.00
	1912	29,005	100.00	39,158,414	100.00
	1913	21,668	100.00	38,387,009	100.00
	1914	27,506	100.00	37,346,023	100.00
	[1] 1915	29,951	100.00	37,011,656	100.00

[1] The data here shown for 1915 are the computed totals by classes of mills.
[2] The total for 1909 differs from that shown in other tables because 4,543 mills, cutting a total of 124,966,000 feet, or less than 50 M feet each, are omitted above.

Figure 2 on pages 10 and 11 shows graphically the production by classes of mills and the total cut in each State.

PRODUCTION BY STATES.

Table 3 shows the reported lumber production by States for the years 1899 to 1914 and the computed State totals for 1915. Because of the closer touch of the western offices of the Forest Service with the mills in their territory, and the consequent greater accuracy of the estimates of probable 1915 total cut of the Western States, the figures for these States are not rounded off as are the corresponding figures for other States. The many thousand mills east of the Rocky Mountains make only an approximate estimate possible.

Table 3 is designed to show the changes which are taking place in the regional production of the country's supply of lumber. The total reported cuts for each State for each of the years indicated are shown on one line and can readily be followed across the page for the purpose of noting rise or decline. In general, the table indicates the declining cut in the Northeastern, Lake, and Central States and

TABLE 3.—*Total number of active sawmills reporting, and quantity of lumber reported, by States, 1899–1914 and computed 1915 totals.*

State.	1915 (29,951 mills).[1]	1914 (27,506 mills).[2]	1913 (21,668 mills).	1912 (29,005 mills).	1911 (28,107 mills).[3]	1910 (31,934 mills).[3]	1909 (46,584 mills).	1908 (31,231 mills).[3]	1907 (28,850 mills).[3]	1906 (22,398 mills).	1904 (18,277 mills).[2]	1899 (31,833 mills).
	M feet b. m.	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*
United States....	[4] 37,011,656	[4] 37,346,023	[4] 38,387,009	[4] 39,158,414	[4] 37,003,207	[4] 40,018,282	44,509,761	33,224,369	40,256,154	37,550,736	[4] 34,135,139	35,084,166
Washington	3,950,000	3,946,189	4,592,053	4,099,775	4,064,754	4,097,492	3,862,916	2,915,928	3,777,606	4,305,053	2,485,628	1,429,032
Louisiana	3,900,000	3,956,434	4,161,560	3,876,211	3,566,456	3,733,900	3,551,918	2,722,421	2,972,119	2,796,395	2,459,327	1,115,366
Mississippi	2,300,000	2,280,966	2,610,581	2,381,898	2,041,615	2,122,205	2,572,669	1,861,016	2,094,485	1,840,250	1,727,391	1,206,265
North Carolina	2,090 000	2,227,854	1,957,258	2,193,308	1,798,724	1,824,722	2,177,715	1,136,796	1,622,387	1,222,974	1,318,411	1,286,638
Arkansas	1,800,000	1,796,780	1,911,647	1,821,811	1,777,303	1,844,446	2,111,308	1,656,991	1,988,504	1,839,368	1,680,536	1,623,987
Texas	1,750,000	1,554,005	2,081,471	1,902,201	1,681,080	1,884,134	2,099,130	1,524,008	2,229,590	1,741,473	1,406,473	1,232,404
Oregon	1,690,000	1,817,875	2,098,467	1,916,160	1,803,698	2,081,633	1,898,995	1,468,158	1,635,563	1,604,894	987,107	734,538
Alabama	1,500,000	1,494,732	1,523,936	1,378,151	1,226,212	1,465,623	1,691,001	1,152,079	1,224,967	1,009,783	1,243,988	1,101,386
Virginia	1,500,000	1,488,070	1,273,953	1,569,997	1,359,790	1,652,192	2,101,716	1,198,725	1,412,477	1,063,241	949,797	959,119
Wisconsin	1,210,000	1,391,001	1,493,353	1,498,876	1,761,986	1,891,291	2,025,038	1,613,315	2,003,279	2,331,305	2,623,157	3,389,166
California	[5] 1,130,000	1,303,183	1,183,380	1,203,059	1,207,561	1,254,826	1,143,507	996,115	1,345,943	1,348,559	1,077,499	737,035
Florida	1,110,000	1,073,821	1,055,047	1,067,525	983,824	992,091	1,201,734	730,906	839,058	888,137	812,693	790,373
Michigan	1,100,000	1,214,435	1,222,983	1,488,827	1,466,751	1,681,081	1,889,724	1,478,252	1,827,685	2,094,279	2,006,670	3,018,338
Minnesota	1,100,000	1,312,230	1,149,704	1,436,726	1,485,015	1,457,734	1,561,508	1,286,122	1,600,716	1,794,144	1,942,248	2,342,338
West Virginia	1,100,000	1,118,480	1,249,559	1,318,732	1,387,786	1,376,737	1,472,942	1,097,015	1,395,979	976,173	855,889	778,051
Maine	1,000,000	992,594	834,673	882,128	828,417	860,273	1,111,565	929,350	1,103,808	1,088,747	863,860	784,647
Georgia	1,000,000	1,026,191	844,284	941,291	801,611	1,041,617	1,342,249	904,668	853,697	831,675	1,135,910	1,311,917
Pennsylvania	950,000	864,710	781,547	992,180	1,048,606	1,241,199	1,462,771	1,203,041	1,734,729	1,620,881	1,738,972	2,333,278
South Carolina	800,000	701,540	752,184	816,930	584,872	706,831	897,660	560,888	649,058	566,928	609,769	466,429
Tennessee	800,000	885,035	872,311	932,572	914,579	1,016,475	1,223,849	790,642	894,968	634,587	775,885	950,958
Idaho	777,000	763,508	652,616	713,575	765,670	745,984	645,800	518,625	513,788	418,944	211,447	65,363
Kentucky	560,000	596,392	541,531	641,296	632,415	753,556	860,712	658,539	912,908	661,299	586,371	774,651
New Hampshire	500,000	482,744	309,424	479,499	388,619	443,907	649,606	606,760	754,023	539,259	491,591	572,447
New York	475,000	486,195	457,720	502,351	526,283	506,074	681,440	781,391	848,894	810,949	581,976	878,448
Ohio	400,000	286,063	414,943	499,834	427,161	490,039	542,904	459,259	529,087	438,775	420,905	990,497
Missouri	350,000	370,571	416,608	422,470	418,586	501,691	660,159	458,938	518,774	507,084	553,940	723,754
Indiana	350,000	298,571	332,993	401,017	360,613	422,963	556,418	411,868	504,790	447,808	563,853	1,036,999
Montana	328,000	317,842	357,974	272,174	228,416	319,089	308,582	311,533	343,814	328,727	236,430	255,685
Vermont	260,000	249,608	194,647	235,983	239,254	284,815	351,571	304,017	373,660	329,422	337,238	375,809
Massachusetts	250,000	143,094	224,580	259,329	273,317	239,206	361,200	384,526	364,231	354,483	262,467	344,190
Oklahoma	230,000	200,594	140,284	168,806	143,869	164,663	225,730	158,756	140,015	49,737	32,730	22,104
Maryland	165,000	162,097	140,469	174,320	144,078	154,554	267,939	168,534	213,786	219,098	166,469	183,711
Illinois	110,000	66,227	102,902	122,528	96,651	113,506	170,181	123,319	141,317	141,374	211,545	388,469
Connecticut	90,000	81,883	93,730	109,251	124,661	126,463	168,371	137,855	140,011	124,880	69,376	108,093
Arizona	75,915	78,667	77,363	76,287	73,139	72,655	62,731	43,287	72,134	56,960	55,601	36,182

Colorado	74,500	102,117	74,602	88,451	95,908	121,398	141,710	117,036	134,239	110,212	141,914	133,746
New Mexico	65,787	57,167	65,818	82,650	83,728	83,544	91,987	79,439	113,204	103,079	81,113	30,880
New Jersey	45,000	48,748	27,248	34,810	28,639	36,542	61,620	31,930	39,942	36,253	41,058	74,118
Iowa	35,000	11,443	21,676	46,593	59,974	75,446	132,021	97,242	144,271	163,747	281,521	352,411
Delaware	25,000	25,517	18,039	28,285	23,853	46,642	55,440	41,184	50,892	44,487	30,416	35,955
South Dakota	22,562	18,744	19,103	20,986	13,046	16,340	31,057	25,859	34,841	22,634	13,705	31,704
Wyoming	17,000	11,852	12,940	13,560	33,309	30,931	28,602	18,822	17,479	13,213	7,990	16,963
Rhode Island	15,000	15,902	14,984	14,421	9,016	11,392	25,489	30,528	32,855	21,528	15,398	18,528
Utah	10,892	8,680	5,403	9,055	10,573	11,786	12,638	15,059	14,690	7,768	12,630	17,548
All other States	(6)	[7] 15,672	[7] 19,461	[7] 22,525	[7] 11,786	[7] 12,594	[7] 15,946	[8] 10,627	[8] 5,891	[9] 170	[10] 23,245	[10] 24,646

[1] Figures shown are computed totals for 1915.
[2] Custom mills excluded.
[3] Includes also exclusive lath and shingle mills reporting (1,500 estimated).
[4] Mills cutting less than 50 M feet per year excluded.
[5] Includes cut of two mills in Nevada.
[6] Kansas and Nebraska mills reported less than 50 M feet each, and these States therefore omitted.
[7] Includes Kansas, Nebraska, and Nevada.
[8] Includes Kansas and Nevada.
[9] Kansas.
[10] Includes Alaska, Kansas, Nebraska, Nevada, and North Dakota in 1899.

the increasing cut in the Southern and Northwestern States. Abnormal conditions in 1914 and 1915 caused departures from the general trend.

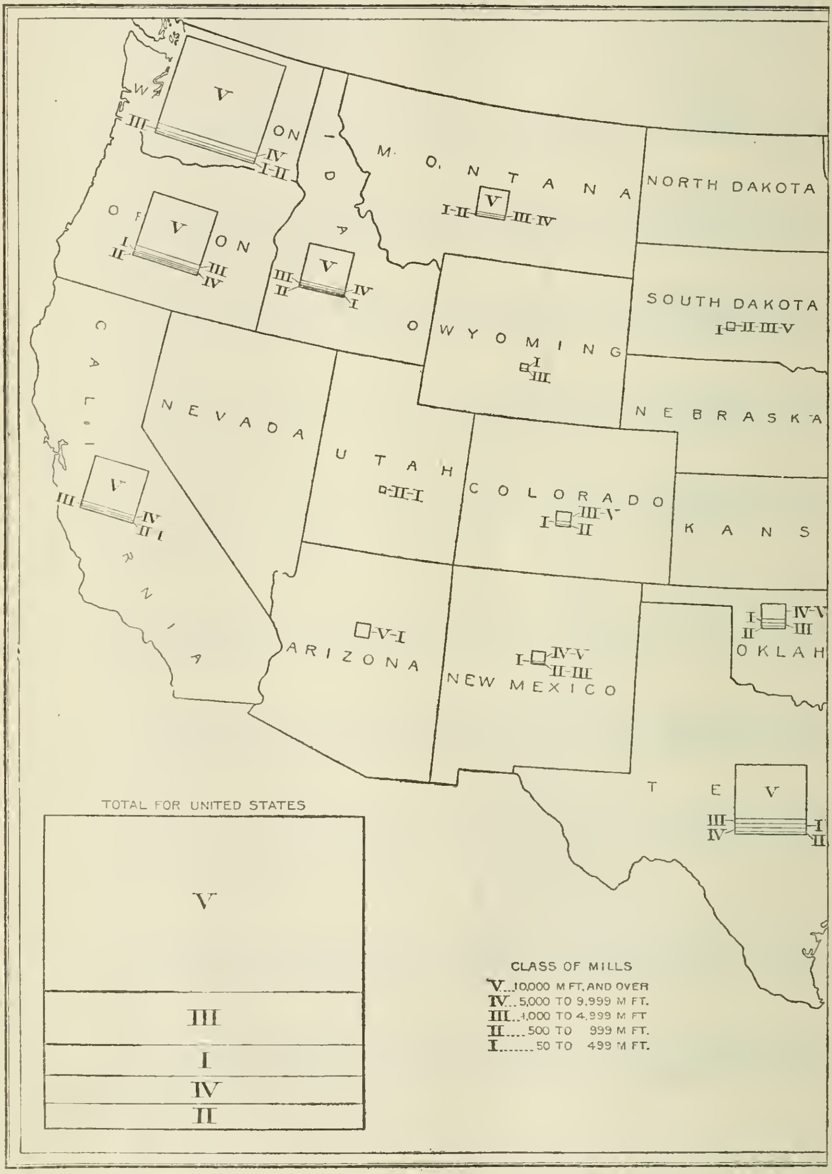
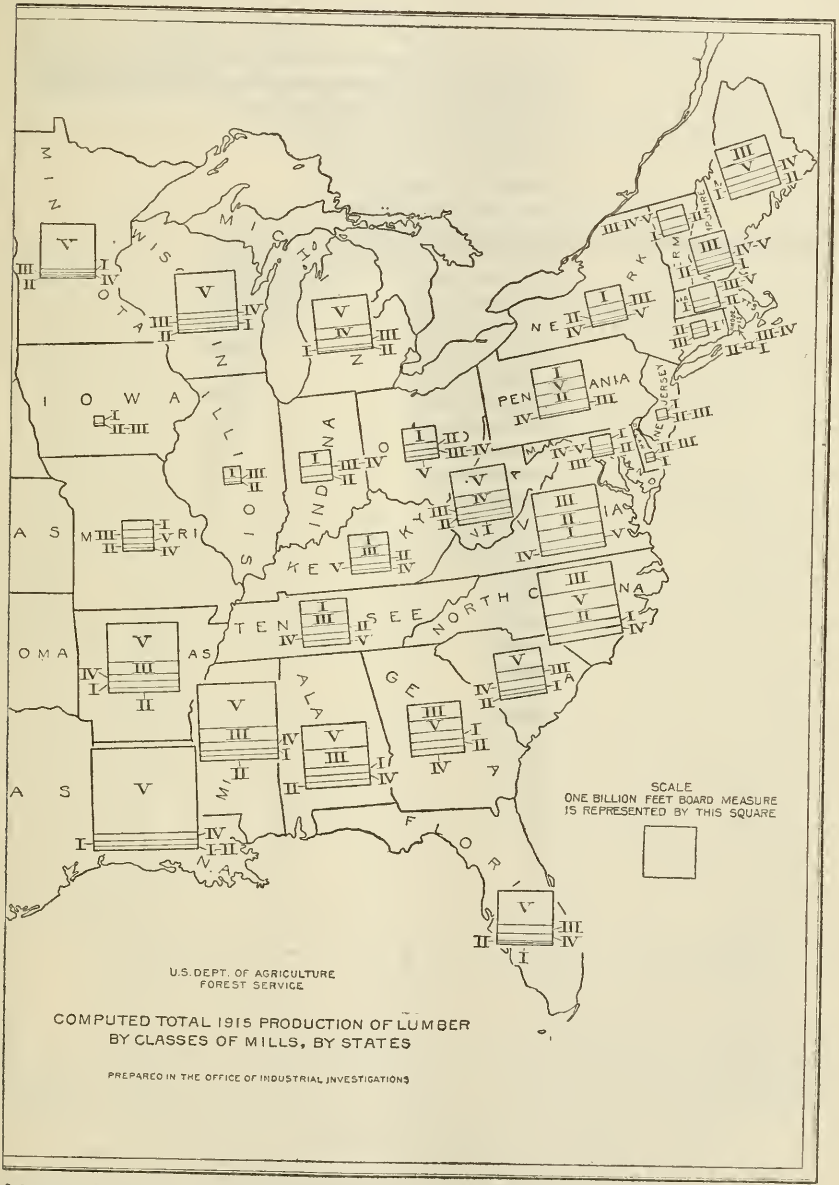


FIG. 2.—Computed total 1915 production

Though the total number of mills reporting varies greatly with different years, the bulk of the lumber cut was probably reported, since mills not reporting were undoubtedly those of the smallest size. For some years it has been possible to show the actual number of sawmills reporting; in other years the figures include an inseparable number of exclusive lath and shingle mills. The figures for



of lumber by classes of mills, by States.

1910 to 1915, inclusive, are for mills cutting 50,000 feet annually and up; and the figures for previous years cover all mills reporting, except that custom mills were excluded in 1914 and 1904.

Data for 1905 are omitted from Tables 3 and 4; only 11,666 mills reported for that year and the results are not complete enough to be comparable with the figures for other years.

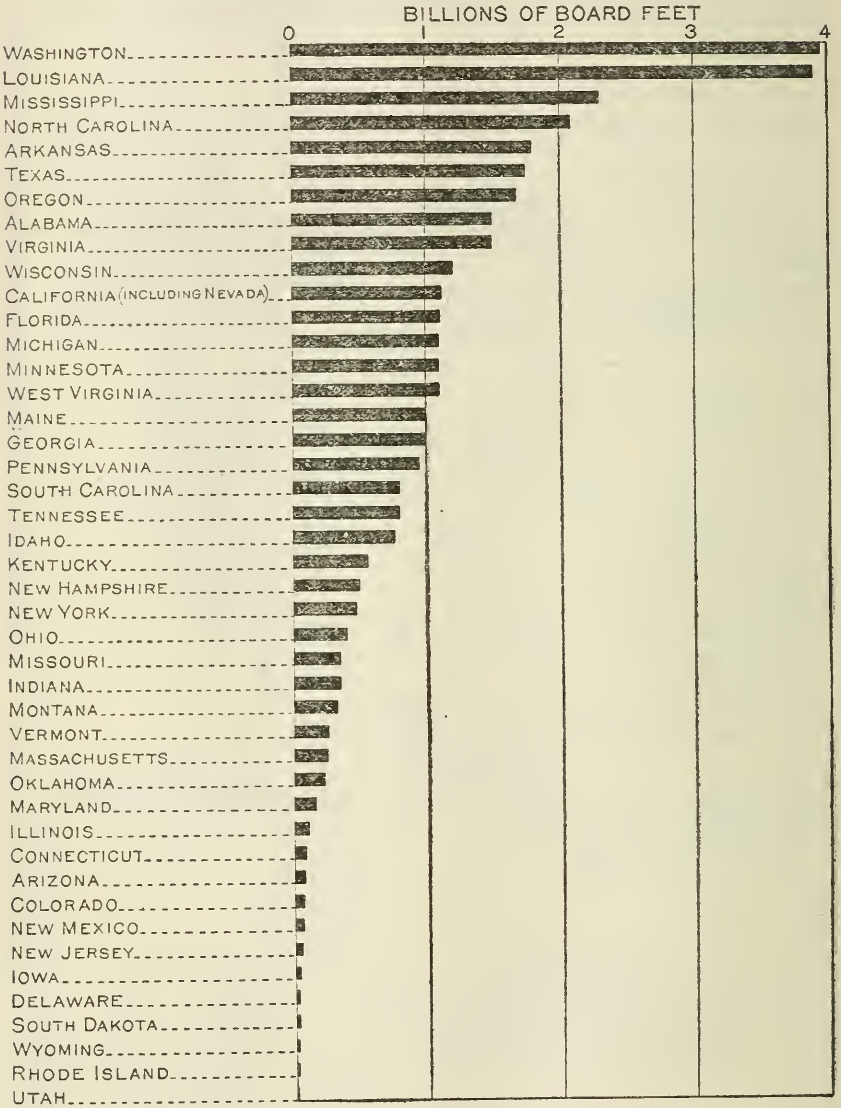


FIG. 3.—Computed total lumber production in 1915, by States.

Figure 3 shows graphically the total production in each State in 1915.

PRODUCTION BY KINDS OF WOOD

Table 4 on page 14 shows the reported lumber production by kinds of wood for 1899 to 1914 and similar computed totals for 1915. There is thus indicated the trend of production in each of the important kinds of lumber. The more accurate 1915 estimates for the exclusive western species are due to the closer touch of the western offices of the Forest Service with the small number of western mills as compared with the many thousands in the eastern half of the country. It will be seen, as in Table 3, that, in general, the production of those woods cut in the Northeastern, Lake, and Central States is declining, while the production of those cut in the Southern and Northwestern States is increasing. This, of course, does not hold true in every case. For instance, the fluctuating markets of 1914 and 1915 caused Douglas fir production to drop but spruce to rise.

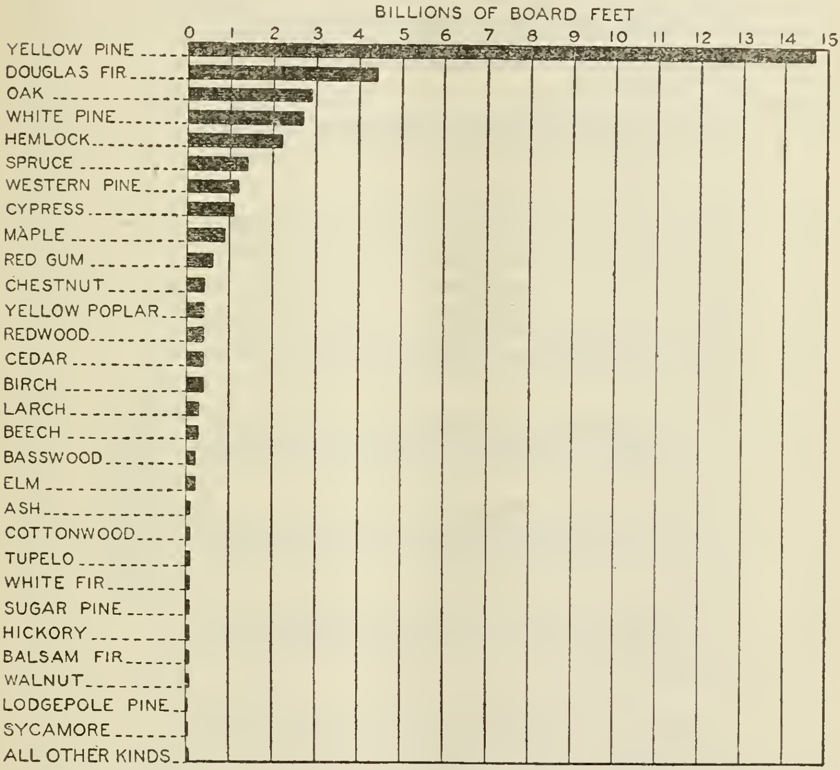


FIG. 4.—Computed total lumber production in 1915, by kinds of woods.

Figure 4 is a graphic representation of the 1915 lumber cut by kinds of wood.

TABLE 4.—*Quantity of each kind of lumber reported, 1899-1914, and computed total 1915 production.*

Kind of wood.	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1904	1899
	M feet b. m.	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*
Total	[1] 37,011,656	37,346,023	38,387,009	39,158,414	37,003,207	40,018,282	44,509,761	33,224,369	40,256,154	37,550,736	[2] 34,135,139	[2] 35,084,166
Yellow pine	14,700,000	14,472,804	14,839,363	14,737,052	12,896,706	14,143,471	16,277,185	11,236,372	13,215,185	11,661,077	11,521,681	9,657,676
Douglas fir	4,431,249	4,763,693	5,556,096	5,175,123	5,054,243	5,203,644	4,856,378	3,675,114	4,748,872	4,969,843	2,928,409	1,736,507
Oak	2,970,000	3,278,908	3,211,718	3,318,952	3,098,444	3,522,098	4,414,457	2,771,511	3,718,760	2,820,393	2,902,855	4,438,027
White pine	2,700,000	2,632,587	2,568,636	3,138,227	3,230,584	3,352,183	3,900,034	3,344,921	4,192,708	4,583,727	5,332,704	7,742,391
Hemlock	2,275,000	2,165,728	2,319,982	2,426,554	2,555,308	2,836,129	3,051,399	2,530,843	3,373,016	3,537,329	3,268,787	3,420,673
Spruce	1,400,000	1,245,614	1,046,816	1,238,600	1,261,728	1,449,912	1,748,547	1,411,992	1,726,797	1,644,987	1,303,886	1,448,091
Western yellow pine	1,293,985	1,327,365	1,258,528	1,219,444	1,330,700	1,562,106	1,499,985	1,275,550	1,527,195	1,386,777	1,290,626	945,432
Cypress	1,100,000	1,013,013	1,097,217	997,227	981,527	935,659	955,635	743,297	757,639	839,276	749,592	495,836
Maple	900,000	909,763	901,487	1,020,864	951,667	1,006,637	1,106,604	874,983	939,073	882,878	587,558	633,466
Red gum	655,000	675,380	772,514	694,260	582,967	610,208	706,945	589,347	689,200	453,678	523,990	285,417
Chestnut	490,000	540,591	505,802	554,230	529,022	535,049	663,891	539,341	653,239	407,379	243,537	206,688
Yellow poplar	464,000	519,221	620,176	623,289	659,475	734,926	858,500	654,122	862,849	677,670	853,554	1,115,242
Redwood	420,294	535,199	510,271	496,796	489,768	543,493	521,630	404,802	569,450	659,678	519,267	360,167
Cedar	420,000	499,903	358,444	329,000	374,925	415,039	346,008	272,764	251,002	357,845	223,035	232,978
Birch	415,000	430,667	378,739	388,272	432,571	420,769	452,370	386,367	387,614	370,432	224,009	132,601
Larch	375,000	358,561	395,273	407,064	368,216	382,514	421,214	382,466	324,509	289,473	31,784	50,619
Beech	360,000	376,464	365,501	435,250	403,881	437,325	511,244	410,072	430,005	275,661	(3)	(3)
Basswood	260,000	264,656	257,102	296,717	304,621	344,704	399,151	319,505	381,088	376,838	228,041	308,069
Elm	210,000	214,294	214,532	262,141	236,108	265,107	347,456	273,845	260,579	224,795	258,330	456,731
Ash	190,000	189,499	207,816	234,548	214,398	246,035	291,209	225,367	252,040	214,460	169,178	269,120
Cottonwood	180,000	195,198	208,938	227,477	198,629	220,305	265,600	232,475	293,161	269,458	321,574	415,124
Tupelo	170,000	124,480	120,420	122,545	98,142	92,071	96,676	69,170	68,842	47,882	(3)	(3)
White fir	125,048	112,627	88,109	122,613	124,307	132,327	89,318	98,120	146,508	104,329	(3)	(3)
Sugar pine	117,701	136,159	149,926	132,416	117,987	103,165	97,191	99,809	115,005	133,640	(3)	53,558
Hickory	100,000	116,113	162,980	278,757	240,217	272,252	333,929	197,372	203,211	148,212	106,824	96,636
Balsam fir	100,000	125,212	93,752	84,261	83,375	74,580	108,702	69,956	53,339	(3)	(3)	(3)
Walnut	90,000	25,573	40,565	43,083	38,293	36,449	46,108	43,681	41,490	48,174	31,455	38,681
Lodgepole pine	26,486	18,374	20,106	22,039	33,014	26,631	23,733	(3)	(3)	(3)	(3)	(3)
Sycamore	25,000	22,773	30,804	49,468	42,836	45,063	56,511	43,332	46,044	(3)	18,002	29,715
All other kinds	47,893	55,624	85,366	82,145	69,548	68,428	62,151	47,873	27,734	164,845	496,461	[2] 511,721

[1] Computed total 1915 production by kinds of wood.
[2] Includes lumber cut in Alaska.
[3] Not separately reported.

The apparently large increase in the cut of tupelo, which includes black gum, during 1915 is believed to be due to the fact that in previous years many mills in the Atlantic and Central States reported their cut of black gum under red gum. The actual cut of tupelo in 1915 was undoubtedly less than in 1914. In Louisiana, where the mills distinguish between tupelo and red gum, the cut of tupelo was one-third less.

The rather consistent decline in the cut of hickory lumber, while pointing to the exhaustion of hickory stumpage in many sections, really indicates that hickory timber is more and more being cut, as recommended by the Forest Service, into more profitable dimension stock for handle and vehicle manufacturers. Dimension stock is not reported as lumber. The hickory lumber reported should, according to the best standard of utilization, be thick stock for the special industries demanding hickory.

The unusually big production of walnut lumber in 1915 was largely caused by orders for thick lumber to be manufactured into gunstocks for use in Europe.

In the portion of the bulletin which follows, the principal kinds of lumber are discussed separately. While the computed total cut of each wood is shown in the tables, only the actual production reported by the mills is given for each State, since it is felt that this indicates sufficiently a State's relative position as a producer of each wood.

The average values given in the tables following were compiled from reports made by about one-half of the 16,815 mills which reported their lumber cut. Values were reported, however, by a part of each class of mills in each State, and the weight of the production of each class was considered in the computations, so the results are very fair average values. Differences in State values are due only in part to distance from consuming markets and to supply and demand. Other factors are quality of timber, how well the lumber is manufactured, and the efficiency of sales organizations.

In the case of those kinds of wood comprising more than one species recognized by the lumber trade, the principal species cut in each State are noted in the tables. The standard name given for each species is that adopted by the Forest Service, and is in most cases the one now used by the lumber trade. The Latin scientific names of all species are given to facilitate reference, especially in the case of foreign readers.

YELLOW PINE.

Yellow pine lumber is produced chiefly in the Southern States. Three species—the longleaf, loblolly, and shortleaf—supply most of the stumpage, while minor yellow pines are cut to a limited extent. The lumber known commercially as North Carolina pine, and coming from Virginia, North Carolina, and South Carolina, includes both loblolly and shortleaf pine. Slash pine is usually cut and sold along with longleaf pine. The several species, in order of importance, are:

Longleaf pine (*Pinus palustris*): Also commonly called hard pine and Georgia pine and exported as pitch pine. Cut principally in the Gulf States.

Loblolly pine (*Pinus tæda*): "Loblolly" is not used generally by the trade, which calls this pine shortleaf, oldfield, rosemary, and Virginia pine. Cut mostly in Virginia, North Carolina, South Carolina, Arkansas, and Texas, and to a less extent in the other Gulf States and Georgia.

Shortleaf pine (*Pinus echinata*): Cut mostly in Arkansas, Virginia, North Carolina, South Carolina, Louisiana, and Mississippi, and to a less extent in the other yellow-pine States.

Slash (or Cuban) pine (*Pinus caribæa*): Cut in Georgia and Gulf States east of Mississippi River.

Scrub pine (*Pinus virginiana*): Also called Jersey pine. Middle Atlantic States.

Pitch pine (*Pinus rigida*): Middle Atlantic and Northern States.

Spruce pine (*Pinus glabra*): Gulf States.

Pond pine (*Pinus serotina*): South Atlantic States.

Sand pine (*Pinus clausa*): Florida and Alabama.

Table-mountain pine (*Pinus pungens*): Appalachian Mountains.

TABLE 5.—*Reported production of yellow pine lumber, 1915.*

[Computed total production in United States, 14,700,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		6,006	12,177,335	100.0	$12.41
Louisiana	Longleaf	205	2,881,615	23.7	12.35
Mississippi	do	512	1,657,887	13.6	12.30
Texas	Longleaf and loblolly	238	1,557,270	12.8	12.58
North Carolina	Loblolly and shortleaf	1,194	1,130,144	9.3	12.21
Arkansas	Shortleaf and loblolly	391	1,082,155	8.9	12.99
Alabama	Longleaf	618	1,023,306	8.4	12.13
Florida	do	185	830,815	6.8	12.29
South Carolina	Loblolly and shortleaf	380	592,184	4.9	12.56
Virginia	do	907	562,926	4.6	12.59
Georgia	Longleaf and loblolly	561	525,747	4.3	11.93
Oklahoma	Shortleaf	51	161,951	1.3	12.76
Missouri	do	84	50,421	.4	12.15
Tennessee	do	235	48,523	.4	11.78
Maryland	Loblolly and shortleaf	129	25,625	.2	13.19
Kentucky	Shortleaf	76	12,909	.1	13.47
All other States (see Summary, p. 38).		240	33,857	.3	

DOUGLAS FIR.

Douglas fir (*Pseudotsuga taxifolia*) of the Western States is available in larger stands than any other single species in the United

States, but the past and present total annual production of "yellow pine," including longleaf, shortleaf, loblolly, and several species of minor importance, far exceeds the yield of Douglas fir. The wood of Douglas fir is quite similar to that of longleaf pine in many of its properties and uses. It is sold under the name of Douglas fir, Oregon pine, red fir, yellow fir, Douglas spruce, Washington fir, Oregon fir, and locally in California as spruce.

TABLE 6.—*Reported production of Douglas fir lumber, 1915.*

[Computed total production in United States, 4,431,249 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	1,017	4,121,897	100.0	$10.59
Washington	317	2,754,179	66.8	10.56
Oregon	309	1,119,395	27.2	10.66
California	73	117,951	2.9	10.27
Idaho	152	76,283	1.8	10.05
Montana	55	41,464	1.0	12.15
All other States (see Summary, p. 38)	140	12,625	.3	....

OAK.

The several commercial oaks furnish the largest quantity of any kind of hardwood lumber. The general lumber trade calls all oak lumber either white or red oak. These trade names are based on the appearance of the two general kinds of lumber cut from oak trees, white oak lumber being light in color and dense and red oak lumber being somewhat reddish and porous. Since these two kinds of lumber are supplied by distinct groups of botanical white and red oaks, the trade distinction is logical. The bulk of oak lumber is cut from less than a dozen species. The largest part of the oak lumber is furnished by white oak and red oak, chestnut oak and Texan red oak being of next importance. Following is a list of the principal commercial oaks, divided into two groups.

WHITE OAKS.

White oak (*Quercus alba*) is the white oak common throughout the eastern half of the United States.

Chestnut (or rock) oak (*Quercus prinus*) occurs in the Appalachian Mountain region.

Post oak (*Quercus stellata*) and bur oak (*Quercus macrocarpa*) have about the same range as white oak, but are not so abundant.

Overcup oak (*Quercus lyrata*) and cow (or basket) oak (*Quercus michauxii*) are the most important of the southern white oaks.

RED OAKS.

Red oak (*Quercus borealis*) is the red oak common in the eastern half of the United States, except in the Gulf States.

Texan red oak (*Quercus texana*) furnishes the main supply of red oak lumber in the lower Mississippi Valley.

Pin oak (*Quercus palustris*) occurs in many Eastern and Central States.

Scarlet oak (*Quercus coccinea*) is a northern and northeastern tree.

Yellow (or black) oak (*Quercus velutina*) is found in most States east of the Rocky Mountains.

Willow oak (*Quercus phellos*) is of commercial importance in the Southern States only.

TABLE 7.—*Reported production of oak lumber, 1915.*

[Computed total production in United States, 2,970,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		9,517	2,070,444	100.0	$18.73
West Virginia	White, red, chestnut	483	291,261	14.1	19.03
Arkansas	White, Texan	439	223,752	10.8	18.40
Kentucky	White, red	584	222,964	10.8	18.79
Tennessee	do	747	210,965	10.2	19.62
Virginia	White, red, chestnut	929	165,592	8.0	16.64
Ohio	do	593	128,562	6.2	21.46
Pennsylvania	do	835	125,581	6.1	19.73
North Carolina	do	709	97,014	4.7	16.42
Missouri	White, red, Texan	388	95,435	4.6	16.51
Mississippi	White, Texan	268	89,469	4.3	18.61
Indiana	White, red	417	80,289	3.9	22.58
Louisiana	White, Texan	88	74,304	3.6	18.48
Alabama	do	291	37,088	1.8	15.68
Texas	do	86	32,564	1.6	16.72
Maryland	White, red, chestnut	157	24,348	1.2	17.37
Illinois	White, red	128	22,660	1.1	19.15
New York	do	639	21,617	1.0	19.70
Georgia	White, Texan	223	20,467	1.0	16.06
Wisconsin	White, red	223	13,658	.6	21.96
New Jersey	do	142	13,155	.6	24.03
All other States (see Summary, p. 40).		1,148	79,699	3.8	

WHITE PINE.

Under "white pine" is included the common white pine of the North and the western, or Idaho, white pine. There are also included Norway pine and jack pine, which are lumbered with white pine in the Lake States and eastward, and for which the mills can not readily give separate figures. The scientific names and commercial range of these species are as follows:

White pine (*Pinus strobus*) is the familiar white pine of the Lake States, the Northeast, and the Appalachian region.

Norway (or red) pine (*Pinus resinosa*) is lumbered in the Lake States and farther east. Botanically it is a yellow pine. The better grades are often sold with white pine, but the wood also has a market under its own name.

Jack pine (*Pinus banksiana*) is a small tree of the Lake States, and is used to a limited extent.

Western white pine (*Pinus monticola*), sometimes called silver pine, supplies the white-pine lumber cut in Idaho, Montana, Washington, and to a limited extent in Oregon.

TABLE 8.—*Reported production of white pine lumber, 1915.*

[Computed total production in United States, 2,700,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		3,349	2,291,480	100.0	$17.44
Minnesota	Eastern white, Norway	171	869,574	38.0	18.41
Idaho	Western white	37	301,600	13.2	17.34
Maine	Eastern white, Norway	478	270,581	11.8	17.10
Wisconsin	do	244	191,306	8.4	19.19
New Hampshire	do	284	189,645	8.3	16.59
Massachusetts	do	223	106,824	4.7	16.44
Washington	Western white	32	90,240	3.9	16.33
Michigan	Eastern white, Norway	181	64,267	2.8	19.84
New York	do	755	60,576	2.6	19.71
Pennsylvania	do	406	39,181	1.7	19.33
Montana	Western white	9	27,330	1.2	16.59
North Carolina	Eastern white	61	16,647	.7	17.48
Vermont	Eastern white, Norway	103	15,040	.6	17.45
West Virginia	Eastern white	72	13,859	.6	18.02
All other States (see Summary, p. 38).		293	34,810	1.5	

HEMLOCK.

Hemlock (*Tsuga canadensis*), the eastern hemlock, is lumbered in the Lake States, the Northeastern States, and the Appalachian region. Western hemlock (*Tsuga heterophylla*) is the main source of hemlock lumber in the Northwestern States, and its production is increasing. Although the mill value is lower, it is superior to the eastern hemlock, and is often sold with Douglas fir. The western mountain or black hemlock (*Tsuga mertensiana*) and the Carolina hemlock (*Tsuga caroliniana*) of the Appalachian region are only occasionally lumbered.

TABLE 9.—*Reported production of hemlock lumber, 1915.*

[Computed total production in United States, 2,275,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		3,739	2,026,460	100.0	$13.14
Wisconsin	Eastern	256	474,371	23.4	13.17
Michigan	do	251	372,512	18.4	13.34
Washington	Western	91	306,570	15.1	9.43
Pennsylvania	Eastern	494	259,914	12.8	15.41
West Virginia	do	134	160,923	7.9	14.73
New York	do	1,038	93,008	4.6	15.26
Maine	do	431	69,568	3.4	14.35
Oregon	Western	27	61,963	3.1	9.58
North Carolina	Eastern	80	46,546	2.3	12.62
New Hampshire	do	236	39,262	1.9	14.22
Vermont	do	281	29,589	1.5	14.87
Virginia	do	86	25,935	1.3	13.90
Tennessee	do	56	23,252	1.1	12.14
Massachusetts	do	125	21,671	1.1	15.28
Kentucky	do	63	18,041	.9	14.11
All other States (see Summary, p. 38).		90	23,335	1.2	

SPRUCE.

Several spruces are cut for lumber, but red and Sitka spruce furnish the greater portion. Red spruce (*Picea rubra*) is the important species in the Northeast and Appalachian region, and Sitka spruce (*Picea sitchensis*) on the northern Pacific coast. In the Northeast black spruce (*Picea mariana*) and white spruce (*Picea canadensis*) are cut to a small extent, while white spruce furnishes the lumber cut in the Lake States. Engelmann spruce (*Picea engelmanni*) is the source of spruce lumber in the Rocky Mountain region. The annual cut of spruce in the Northeast and Northwest is fairly uniform. However, in the Appalachian region, the West Virginia tracts are being cut out, and new tracts are being opened in North Carolina. The 1915 reported cut of spruce in West Virginia was less than one half as much as in 1912, while in North Carolina the mills reported cutting fifteen times as much as in 1912.

TABLE 10.—*Reported production of spruce lumber, 1915.*

[Computed total production in United States, 1,400,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		1,573	1,193,985	100.0	$16.58
Maine	Red	362	362,704	30.4	17.28
Washington	Sitka	49	196,203	16.4	14.08
New Hampshire	Red	138	112,904	9.5	17.67
West Virginia	do	25	91,780	7.7	17.97
North Carolina	do	8	83,601	7.0	17.66
Vermont	do	278	69,134	5.8	17.10
Oregon	Sitka	20	65,327	5.5	13.56
Minnesota	White	91	58,472	4.9	17.78
New York	Red	232	53,185	4.4	17.97
Massachusetts	do	41	34,389	2.9	17.85
All other States (see Summary, p. 38).		329	66,286	5.5	

WESTERN YELLOW PINE.

Western yellow pine (*Pinus ponderosa*) is cut for lumber in every western State from South Dakota to the Pacific coast. Bull pine is a common woods name for the tree. The lumber is generally sold under the trade names of California white pine, New Mexico white pine, western soft pine, and western white pine. The better grades are soft and light, and compete with white pine.

TABLE 11.—*Reported production of western yellow pine lumber, 1915.*

[Computed total production in United States, 1,293,985 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	726	1,252,244	100.0	$14.32
California [1]	91	389,991	31.1	14.89
Idaho	119	201,858	16.1	12.37
Oregon	134	189,203	15.1	16.31
Washington	120	148,789	11.9	14.39
Montana	59	118,920	9.5	13.33
Arizona	14	75,843	6.1	13.21
New Mexico	43	61,466	4.9	13.78
Colorado	75	37,241	3.0	13.06
South Dakota	28	22,457	1.8	16.98
All other States (see Summary, p. 38)	43	6,476	.5	....

[1] Includes 1 mill in Nevada.

CYPRESS.

Bald cypress (*Taxodium distichum*) is the commercial cypress. The principal stand of cypress is in Louisiana, and that State is the principal producer of cypress lumber. Other southern States are next in importance, and some is cut in the Atlantic and Central States. New tracts of cypress have been opened in Florida during the past two years, and the reported lumber cut in that State was 60 per cent more in 1915 than in 1912.

TABLE 11.—*Reported production of western yellow pine lumber, 1915.*

[Computed total production in United States, 1,100,000 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	647	926,758	100.0	$19.85
Louisiana	91	560,751	60.5	20.55
Florida	34	161,123	17.4	20.99
Georgia	39	49,703	5.4	17.61
South Carolina	38	30,062	3.2	17.05
North Carolina	103	27,059	2.9	16.31
Arkansas	112	25,383	2.7	17.53
Missouri	41	23,986	2.6	14.95
Mississippi	70	23,656	2.6	17.65
All other States (see Summary, p. 38)	119	25,035	2.7	....

MAPLE.

The lumber trade recognizes two kinds of maple—hard and soft. Hard-maple lumber comes from the sugar-maple tree and soft-maple lumber from the silver and red species. These three species have a botanical range covering the eastern half of the United States.

Sugar (or hard) maple (*Acer saccharum*) and silver maple (*Acer saccharinum*) are lumbered principally in the Northern States. Red maple (*Acer rubrum*) is most important as a timber tree in the Southern States. Both silver and red maple are commonly called soft maple.

Eastern species of minor importance are mountain maple (*Acer spicatum*) and striped maple (*Acer pennsylvanicum*). Oregon maple (*Acer macrophyllum*) is cut in the Pacific Coast States.

TABLE 13.—*Reported production of maple lumber, 1915.*

[Computed total production in United States, 900,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		4,294	771,223	100.0	$15.21
Michigan	Sugar	279	339,618	44.0	15.32
Wisconsin	do	263	122,016	15.8	14.72
West Virginia	do	213	76,934	10.0	14.97
Pennsylvania	do	537	52,316	6.8	15.53
New York	do	861	45,407	5.9	15.56
Ohio	do	407	32,255	4.2	15.97
Vermont	do	245	22,119	2.9	15.35
Indiana	do	290	15,662	2.0	15.69
All other States (see Summary, p. 40).		1,199	64,896	8.4	

RED GUM.

Red (or sweet) gum (*Liquidambar styraciflua*) is a single species, and what is commercially known as "sap gum" is the sapwood of the red gum tree. It is of most importance commercially in the lower Mississippi Valley, but is also cut farther east and north.

TABLE 14.—*Reported production of red gum lumber, 1915.*

[Computed total production in United States, 655,000 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	1,700	478,099	100.0	$12.54
Arkansas	203	153,091	32.0	12.74
Mississippi	171	110,285	23.1	12.57
Louisiana	48	39,540	8.3	12.11
Missouri	75	28,345	5.9	12.78
Tennessee	190	24,729	5.2	12.89
South Carolina	38	21,821	4.5	11.69
Alabama	82	18,829	3.9	11.97
Texas	41	18,003	3.8	12.32
North Carolina	125	14,831	3.1	10.93
Virginia	139	13,255	2.8	11.66
All other States (see Summary, p. 40)	588	35,370	7.4	

CHESTNUT.

Only one species of chestnut (*Castanea dentata*) is native in the United States. It is lumbered throughout most of its range in the Central and Eastern States. The chestnut-bark disease, or chestnut blight, which has killed much of the timber north of the Potomac River, is now invading the more valuable Appalachian forests. Blight-killed chestnut timber, utilized before it deteriorates on the stump, is suitable for all purposes for which chestnut is used.

TABLE 15.—*Reported production of chestnut lumber, 1915.*

[Computed total production in United States, 490,000 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	3,266	399,473	100.0	$16.17
West Virginia	334	117,989	29.5	15.93
Pennsylvania	691	54,388	13.6	16.42
North Carolina	175	40,876	10.2	15.58
Virginia	355	35,573	8.9	15.31
Tennessee	284	28,484	7.1	15.16
Connecticut	111	27,351	6.9	17.03
Kentucky	249	15,508	3.9	15.67
Massachusetts	134	15,138	3.8	16.32
Maryland	87	14,191	3.6	14.15
New York	435	13,425	3.4	18.89
New Jersey	127	13,301	3.3	19.91
All other States (see Summary, p. 40)	284	23,249	5.8	....

YELLOW POPLAR.

Yellow poplar (*Liriodendron tulipifera*), a single species, is also known as whitewood, poplar, or tulip poplar. The best-known trade name is simply poplar. The Appalachian States constitute the principal producing region.

TABLE 16.—*Reported production of yellow-poplar lumber, 1915.*

[Computed total production in United States, 464,000 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	3,046	377,386	100.0	$22.45
West Virginia	295	100,863	26.7	24.90
Kentucky	364	49,154	13.0	23.24
Tennessee	415	46,129	12.2	22.82
Virginia	438	40,899	10.9	20.30
North Carolina	319	33,168	8.8	19.71
Ohio	244	29,175	7.7	27.76
Alabama	129	22,808	6.1	18.25
Georgia	93	20,343	5.4	19.36
All other States (see Summary, p. 40)	749	34,847	9.2	....

REDWOOD.

Redwood (*Sequoia sempervirens*), which supplies most of the redwood lumber, occurs mostly in California and to a very small extent in southern Oregon. The bigtree (*Sequoia washingtoniana*), the largest tree species in the world, which is found only in California, also supplies a part.

The 1915 estimated total cut of 420,294,000 feet is based on 418,824,000 feet reported by 32 California mills. The average value was $13.54 per M feet f. o. b. mill.

CEDAR.

A number of species are grouped in this bulletin under the common name "cedar." In importance as lumber producers the several species rank as follows:

Western red cedar (*Thuja plicata*): The source of three-fourths of the shingles made in the United States; is also cut for lumber in Washington, Oregon, and Idaho.

Port Orford cedar (*Chamaecyparis lawsoniana*): Cut mostly in Oregon; the principal cedar cut in that State. The 1915 reported cut of cedar in Oregon was 70 per cent more than in 1912.

Northern white cedar, or arborvitae (*Thuja occidentalis*): Cut in the Lake States and Northeastern States.

Incense cedar (*Libocedrus decurrens*): Cut in California.

Southern white cedar (*Chamaecyparis thyoides*), often called juniper: Cut in the Atlantic Coast States.

Red cedar (*Juniperus virginiana* and *J. barbadensis*): Cut mostly in Tennessee, Florida, and Alabama.

Yellow cedar (*Chamaecyparis nootkatensis*): Sometimes lumbered in Washington.

TABLE 17.—*Reported production of cedar lumber, 1915.*

[Computed total production in United States, 420,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		649	352,482	100.0	$16.10
Washington	Western red	102	201,561	57.2	15.40
Oregon	Port Orford	43	39,835	11.3	19.37
Idaho	Western red	22	29,654	8.4	9.44
Virginia	Southern white	29	21,994	6.2	22.53
Maine	Northern white	79	15,700	4.5	14.14
California	Incense	35	12,185	3.5	12.08
Michigan	Northern white	39	8,283	2.3	15.59
Wisconsin	do	47	6,679	1.9	14.66
All other States (see Summary, p. 38).		253	16,591	4.7	

BIRCH.

Two species furnish the bulk of the birch lumber produced, but these are seldom separated in the trade. Yellow birch (*Betula lutea*) is the principal source of lumber in New England, New York, and the Lake States, while sweet (or cherry) birch (*Betula lenta*) is the principal species cut in Pennsylvania and West Virginia. In northern New England paper birch (*Betula papyrifera*), often called canoe or white birch, is the principal source of material for spools, toothpicks, and novelties and some is cut into lumber.

River (or red) birch (*Betula nigra*) is poorer in color and figure than the other birches, but is sometimes cut for lumber in the Southern States. In the lumber trade "red birch" means lumber cut from the heartwood of yellow or sweet birch.

Western birch (*Betula occidentalis*) is sawed into lumber to a minor extent on the Pacific coast.

White (or gray) birch (*Betula populifolia*) is a small timber tree in New England used for minor purposes.

TABLE 18.—*Reported production of birch lumber, 1915.*

[Computed total production in United States, 415,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		2,197	355,328	100.0	$16.52
Wisconsin	Yellow	247	161,853	45.6	16.77
Michigan	do	178	56,869	16.0	17.11
Vermont	do	240	27,352	7.7	16.09
Maine	Yellow and paper	211	27,138	7.6	16.42
New York	Yellow	420	20,949	5.9	16.23
West Virginia	Sweet	111	17,715	5.0	16.51
New Hampshire	Yellow	115	13,629	3.8	15.94
Pennsylvania	Sweet	276	11,771	3.3	15.73
All other States (see Summary, p. 40).		399	18,052	5.1	

LARCH.

The term "larch" is here used to cover two closely related and similar species, tamarack (*Larix laricina*), cut in the Northern States from Minnesota to Maine, and western larch (*Larix occidentalis*), cut in Montana, Idaho, Washington, and Oregon. Although sold for less at the mill, the lumber of the latter is more valuable than tamarack, because the tree is much larger and the wood has more strength and figure and better finishing properties.

TABLE 19.—*Reported production of larch lumber, 1915.*

[Computed total production in United States, 375,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b mill.
United States		571	348,428	100.0	$10.78
Montana	Western larch	39	115,001	33.0	10.79
Idaho	do	49	111,345	32.0	8.89
Minnesota	Tamarack	118	37,898	10.9	13.90
Wisconsin	do	151	24,231	6.9	13.83
Michigan	do	123	22,368	6.4	14.53
Washington	Western larch	46	21,477	6.2	8.78
Oregon	do	11	15,506	4.4	8.98
All other States (see Summary, p. 38).		34	602	.2	

BEECH.

There is but one kind of beech native to the United States (*Fagus ferruginea*). Beech lumber is cut in nearly all the hardwood States, but Michigan, New York, and the Ohio Valley States are the most important.

TABLE 20.—*Reported production of beech lumber, 1915.*

[Computed total production in United States, 360,000 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	3,329	303,835	100.0	$14.01
Michigan	205	65,998	21:7	14.35
Pennsylvania	376	43,168	14.2	13.95
West Virginia	213	38,952	12.8	13.43
New York	650	32,689	10.8	14.31
Ohio	442	31,923	10.5	14.66
Indiana	338	31,316	10.3	15.41
Kentucky	274	20,578	6.8	12.28
Vermont	172	9,162	3.0	13.75
Tennessee	159	6,556	2.2	11.84
New Hampshire	72	6,016	2.0	13.86
All other States (see Summary, p. 40)	420	17,477	5.7	

BASSWOOD.

Three botanical species of basswood are cut for lumber, but no distinction is made on the market. Common basswood (or linn) (*Tilia americana*) is cut mostly in the Lake States, common basswood and white basswood (*Tilia hetrophylla*) in the Appalachian Mountains, while downy basswood (*Tilia pubescens*) is a scarce tree in the Southern States.

TABLE 21.—*Reported production of basswood lumber, 1915.*

[Computed total production in United States, 260,000 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	2,889	207,607	100.0	$18.89
Wisconsin	286	73,929	35.6	18.94
Michigan	213	28,718	13.8	19.57
West Virginia	191	26,956	13.0	19.13
New York	848	18,114	8.7	19.50
Pennsylvania	220	8,075	3.9	17.30
Ohio	191	7,914	3.8	19.39
Vermont	177	6,200	3.0	17.71
North Carolina	56	6,129	3.0	18.24
Virginia	55	5,131	2.5	18.81
All other States (see Summary, p. 40)	652	26,441	12.7	....

ELM.

Elm lumber is sold as soft and rock elm, the soft elm lumber coming from the botanical species white and slippery. White (or American) elm (*Ulmus americana*) is found in all States east of the Rocky Mountains and furnishes the larger part of the soft elm lumber sold.

Slippery (or red) elm (*Ulmus pubescens*) covers the eastern half of the United States, and is next to white elm in importance.

Cork (or true rock) elm (*Ulmus racemosa*) is found in the Northern States, and is cut mostly in the Lake States.

Wing elm (*Ulmus alata*) and cedar elm (*Ulmus crassifolia*) of the lower Mississippi Valley are sometimes cut for lumber.

TABLE 22.—*Reported production of elm lumber, 1915.*

[Computed total production in United States, 210,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		2,730	177,748	100.0	$16.98
Wisconsin	White	264	42,534	23.9	17.50
Michigan	do	217	35,598	20.0	18.15
Arkansas	do	72	17,055	9.6	15.32
Indiana	do	293	15,129	8.5	18.03
Ohio	do	319	13,815	7.8	18.31
New York	do	570	9,435	5.3	18.16
Missouri	do	135	8,817	5.0	14.83
Tennessee	do	116	7,825	4.4	16.38
Louisiana	do	26	6,031	3.4	15.15
All other States (see Summary, p. 40.)		718	21,509	12.1	....

ASH.

Three kinds of ash are important sources of lumber. White ash (*Fraxinus americana*) is cut mostly in the Central hardwood States and the Northeast, and to some extent in the Lake States. A great deal of the ash lumber cut in the Lake States comes from the black ash (*Fraxinus nigra*), while the same species is cut to considerable extent in the Northeast. Green ash (*Fraxinus lanceolata*) is the principal source of ash lumber in the Southern States. The lumber trade divides ash lumber into white ash and brown ash; white-ash lumber is cut from the white ash and green-ash tree, while brown-ash lumber comes from the black-ash tree. In the Pacific Coast States, Oregon ash (*Fraxinus oregona*) is sometimes cut, while red ash (*Fraxinus pennsylvanica*) is used to a limited extent in the East.

TABLE 23.—*Reported production of ash lumber, 1915.*

[Computed total production in United States, 190,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		3,486	159,910	100.0	$22.15
Arkansas	Green	87	18,957	11.8	23.35
Tennessee	do	193	15,233	9.5	23.37
Louisiana	do	49	14,602	9.1	22.47
Wisconsin	White and black	213	13,733	8.6	19.96
Indiana	White	238	11,006	6.9	23.75
Ohio	do	273	8,616	5.4	24.59
Michigan	White and black	174	7,839	4.9	21.36
Mississippi	Green	79	7,381	4.6	22.51
New York	White and black	702	7,163	4.5	23.90
Kentucky	White	156	6,966	4.4	23.69
All other States (see Summary, p. 40).		1,322	48,414	30.3	

COTTONWOOD.

Cottonwood lumber is cut from a number of related species.

Common cottonwood (*Populus deltoides*) furnishes the bulk of the lumber. It is found in the whole country east of the Rocky Mountains, but is lumbered principally in the lower Mississippi Valley.

Swamp cottonwood (*Populus heterophylla*) is cut with common cottonwood in the lower Mississippi Valley States.

Aspen (or popple) (*Populus tremuloides*), often called poplar, is cut mostly in the Lake States and the Northeast, but also occasionally in the Rocky Mountains and westward.

Large-toothed aspen (*Populus grandidentata*), an eastern species, is not usually distinguished from the other.

Balm of Gilead (*Populus balsamifera*), commonly known as balm, is cut in the Lake States and eastward.

Black cottonwood (*Populus trichocarpa*) is lumbered on the Pacific coast. It is the largest of the cottonwoods.

TABLE 24.—*Reported production of cottonwood lumber, 1915.*

[Computed total production in United States, 180,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		1,037	138,282	100.0	$17.36
Mississippi	Common cottonwood	46	37,139	26.8	18.66
Arkansas	do	39	23,389	16.9	18.14
Louisiana	do	21	17,121	12.4	19.16
Minnesota	Aspen and balm	79	14,074	10.2	12.59
Tennessee	Common cottonwood	49	10,466	7.6	19.33
Michigan	Aspen and balm	51	8,188	5.9	15.44
Missouri	Common cottonwood	57	3,648	2.6	17.76
Iowa	do	59	2,855	2.1	19.32
All other States (see Summary, p. 40).		636	21,402	15.5	

TUPELO.

The term "tupelo" is here used to cover two important and one minor species of the botanical genus Nyssa. Most of the tupelo lumber is cut in the Gulf States from cotton gum (*Nyssa aquatica*), commonly called tupelo. This tree furnishes the lumber sold under the trade name of "tupelo." Black gum (or pepperidge) (*Nyssa sylvatica*) is of next importance and is cut in the Atlantic and Central States; the lumber is sold both as tupelo and black gum. A little lumber is made from water gum (*Nyssa biflora*) in the Southern Atlantic States.

Under "Production by kinds of woods," on page 15, errors on the part of mills in reporting black gum under red gum in previous years are pointed out. The 1915 schedule sent to mills indicated that black gum should be reported under tupelo, and the result was a largely increased reported cut of this species in the Atlantic and Central States.

TABLE 25.—*Reported production of tupelo lumber, 1915.*

[Computed total production in United States, 170,000 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		636	153,001	100.0	$12.25
Louisiana	Cotton gum	45	62,402	40.8	12.79
North Carolina	Black gum	40	16,758	11.0	11.67
Virginia	do	39	15,832	10.3	11.49
Alabama	Cotton gum	30	14,546	9.5	11.23
South Carolina	Black gum	17	7,922	5.2	12.02
Mississippi	Cotton gum	40	7,844	5.1	12.80
Missouri	Black gum	34	5,822	3.8	10.97
Kentucky	do	74	5,198	3.4	12.50
All other States (see Summary, p. 40).		317	16,677	10.9	

WHITE FIR.

White fir is cut only in the West. White fir (*Abies concolor*), also called balsam fir, is the principal source of white fir lumber in all the Western States except Oregon, Washington, Idaho, and Montana. Other species, sold as white fir and therefore here included under that name, are grand fir (*Abies grandis*), silver fir (*Abies amabilis*) sometimes called amabilis fir, noble fir (*Abies nobilis*), red fir (*Abies magnifica*), and alpine fir (*Abies lasiocarpa*). The cut of white fir lumber in Idaho and Montana is increasing.

TABLE 26.—*Reported production of white fir lumber, 1915.*

[Computed total production in United States, 125,048 M feet b. m.]

State.	Principal species cut.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States		236	121,653	100.0	$10.94
California [1]	White fir; red fir	45	50,820	41.8	11.61
Idaho	Grand fir	57	42,906	35.3	10.80
Oregon	Noble fir	51	12,592	10.3	9.41
Washington	Silver fir	27	6,783	5.6	9.11
Montana	Grand fir	6	6,510	5.3	10.40
All other States (see Summary, p. 38).		50	2,042	1.7	

[1] Includes 2 mills in Nevada.

SUGAR PINE.

Sugar pine (*Pinus lambertiana*) is the largest pine in the United States. The wood resembles white pine, and the uses of the two are similar. The estimated total cut of 117,701,000 feet is based on 114,494,000 feet reported by 42 mills in California and 615,000 feet reported by 2 mills in Oregon. The species grows in no other States. The average value for California was $17.41 and for Oregon $15.00.

BALSAM FIR.

One species furnishes all of the balsam fir lumber produced. This is the common balsam fir or balsam (*Abies balsámea*), which is lumbered in the Northeast and in the Lake States.

TABLE 27.—*Reported production of balsam fir lumber, 1915.*

[Computed total production in United States, 100,000 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	545	71,358	100.0	$13.79
Maine	235	37,279	52.2	14.08
Minnesota	76	14,159	19.9	12.65
Vermont	94	8,849	12.4	14.28
Michigan	39	4,491	6.3	13.99
New Hampshire	46	3,705	5.2	13.82
Wisconsin	39	2,446	3.4	13.61
All other States (see Summary, p. 38)	16	429	.6	

HICKORY.

Several species of hickory are cut for lumber in this country; the wood grows naturally nowhere else in the world. The species cut most are shagbark (*Carya ovata*), shellbark (*Carya laciniosa*), pignut (*Carya glabra*), bitternut (*Carya cordiformis*), and mockernut (*Carya alba*). The Lower Mississippi and the Ohio Valleys supply the bulk of the hickory lumber. Industries which use the largest quantities of hickory prefer it in the form of blanks, squares, or billets. It is usually more profitable to saw hickory into such dimension stock than into lumber. Since in each of the principal producing States all the commercial hickories are cut, no segregation by species can be indicated in the table.

TABLE 28.—*Reported production of hickory lumber, 1915.*

[Computed total production in United States, 100,000 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	2,526	86,015	100.0	$23.35
Arkansas	144	13,443	15.6	23.76
Tennessee	205	11,933	13.9	24.08
West Virginia	205	9,372	10.9	21.81
Kentucky	181	8,708	10.1	22.21
Indiana	274	7,150	8.3	26.29
Ohio	312	6,851	8.0	24.07
Missouri	120	5,236	6.1	27.03
Pennsylvania	264	4,453	5.2	20.04
Louisiana	15	3,770	4.4	24.35
Mississippi	51	3,220	3.7	23.10
All other States (see Summary, p. 40)	755	11,879	13.8	....

WALNUT.

Walnut lumber is cut from the common black walnut (*Juglans nigra*), which grows throughout the eastern half of the country, but is most available in the Central States. Values for walnut were higher in 1915 than for previous years, and the cut therefore greater. The demand for gunstock material accounts for this. In Illinois practically all of the walnut reported was cut by two or three mills which specialized on gunstocks, and so the average value for Illinois is higher than for other States, where the larger number of mills reporting included many cutting low grade lumber only.

TABLE 29.—*Reported production of walnut lumber, 1915.*

[Computed total production in United States, 90,000 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	1,293	65,144	100.0	$48.47
Missouri	86	17,954	27.6	48.78
Indiana	223	11,267	17.3	44.83
Tennessee	205	9,123	14.0	44.28
Illinois	33	7,077	10.9	62.59
Ohio	149	6,917	10.6	48.21
Iowa	45	4,439	6.8	45.76
Kentucky	149	4,007	6.1	45.36
All other States (see Summary, p. 40)	403	4,360	6.7	....

LODGEPOLE PINE.

Lodgepole pine (*Pinus contorta*) is a small tree cut for common lumber in the northern Rocky Mountain States. It is also extensively utilized for hewn railroad ties.

TABLE 30—*Reported production of lodgepole pine lumber, 1915.*

[Computed total production in United States, 26,486 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	134	22,672	100.0	$13.57
Colorado	32	9,800	43.2	12.44
Wyoming	42	8,737	38.6	14.00
Montana	19	1,684	7.4	14.14
Utah	14	1,387	6.1	16.49
Idaho	26	1,054	4.7	15.78
Washington	1	10	(1)	10.00

[1] Less than one-tenth of 1 per cent.

SYCAMORE.

The common sycamore (*Platanus occidentalis*) furnishes the lumber of this name. The central Mississippi Valley States form the principal producing region.

TABLE 31—*Reported production of sycamore lumber, 1915.*

[Computed total production in United States, 25,000 M feet b. m.]

State.	Number of active mills reporting.	Quantity reported, M feet b. m.	Per cent.	Average value per M feet f. o. b. mill.
United States	876	19,729	100.0	$13.83
Arkansas	42	4,645	23.5	13.72
Indiana	199	3,309	16.8	14.36
Tennessee	80	2,739	13.9	12.66
Missouri	104	2,144	10.9	14.55
Kentucky	94	1,678	8.5	13.17
Ohio	105	1,522	7.7	15.53
All other States (see Summary, p. 40)	252	3,692	18.7	....

MINOR SPECIES.

Woods cut in too small quantities to be presented in separate tables are included under minor species. Some of the species are native and some foreign. The foreign woods are imported in log form and sawed at special mills located in the States designated in Table 32.

True mahogany (*Swietenia mahagoni* and *S. macrophylla*) comes from tropical America. Other so-called mahoganies come from Africa, South America, India, and the Philippines.

Black willow (*Salix nigra*) is sawed into lumber in the lower Mississippi Valley.

Cherry (*Prunus serotina*) is a scarce but valuable tree, and is cut in many Eastern States.

Buckeye (*Aesculus octandra*) is a tree cut for lumber and often known as yellow buckeye.

Cucumber (*Magnolia acuminata*) is cut in Ohio, North Carolina, New York, and intervening States. The lumber frequently goes to market as "poplar saps" or the sapwood of yellow poplar.

Magnolia (*Magnolia grandiflora*), also known in the South as evergreen magnolia, furnishes the magnolia lumber of commerce.

Hackberry (*Celtis occidentalis*) and sugarberry (*Celtis mississippiensis*) are both cut as hackberry lumber, mostly in the Southern States.

Black (or yellow) locust (*Robinia pseudacacia*) is usually made into insulator pins, tree nails, and hubs, but seldom into lumber. It is very durable, and some of the lumber reported may have been sawed posts. Honey locust (*Gleditsia tricanthos*) was probably the source of most of the locust lumber.

Butternut (*Juglans cinerea*), although much less valuable than walnut, is occasionally cut in the Northern and Central States.

Pecan (*Carya pecan*) is a southern tree of the hickory family, more valuable for nuts than lumber, and with inferior wood.

Most of the eucalyptus lumber comes from blue gum (*Eucalyptus globulus*), which is an Australian tree, successfully planted in California. Other species are growing in California and sometimes furnish sawlogs.

Box elder (*Acer negundo*) is a member of the maple family, but supplies inferior lumber.

Red alder (*Alnus rubra*) is one of the few Pacific coast hardwoods.

Spanish cedar (*Cedrela odorata*) is imported in large quantities to make cigar-box veneer, and is sometimes sawed into lumber.

Sassafras (*Sassafras variifolium*) is sometimes cut in hardwood operations.

Limber pine (*Pinus flexilis*) is a scarce Rocky Mountain species, supplying inferior "white pine" lumber.

Hornbeam (or ironwood) (*Ostrya virginiana*) is cut in the North when a very tough wood is wanted.

Jenisero, prima vera, and white mahogany (*Tabebuia donnell-smithii*) are different names for the same species, which grows in Mexico and Central America.

Holly (*Ilex opaca*) yields a white wood similar to maple.

Osage orange, or Bois d'Arc (*Maclura pomifera*), is usually cut into vehicle stock.

TABLE 32.—*Minor species, 1915.*

[Computed total production in United States, 47,893 M feet b. m.]

Kind of wood.	Number of active mills reporting.	Quantity reported, M feet b. m.	Average value per M feet f. o. b. mill.	States reporting.
Total	....	37,825	....	
Mahogany	5	14,036	$101.13	Louisiana, Kentucky, Indiana, Tennessee, Ohio.
Willow	21	8,355	10.99	Mississippi, Tennessee, Louisiana, Arkansas, Missouri, Iowa, New York, New Jersey, Pennsylvania, Indiana.
Cherry	436	6,992	23.69	West Virginia, New York, Pennsylvania, North Carolina, Indiana, Ohio, Virginia, Tennessee, Michigan, Vermont, Wisconsin, Massachusetts, New Hampshire, Arkansas, Alabama, Connecticut, Kentucky.
Buckeye	41	3,930	15.01	North Carolina, West Virginia, Virginia, Tennessee, Kentucky, Alabama, Iowa, New York.
Cucumber	24	945	22.06	West Virginia, North Carolina, New York, Pennsylvania, Ohio, Maryland.
Magnolia	9	731	16.49	Mississippi, Louisiana, Texas.
Hackberry	22	671	15.03	Arkansas, Alabama, Oklahoma, Mississippi, Indiana, Texas, Missouri, Michigan, Illinois.
Locust	46	618	15.15	Arkansas, Tennessee, West Virginia, Virginia, New York, Illinois, North Carolina, Iowa, Indiana, Missouri, Pennsylvania, Maryland, Connecticut, Texas.
Butternut	64	499	19.65	West Virginia, Wisconsin, Indiana, New York, Pennsylvania, North Carolina, Vermont, Virginia, Michigan, Tennessee.
Pecan	8	247	16.36	Arkansas, Texas, Oklahoma, Missouri.
Eucalyptus	1	200	....	California.
Boxelder	3	134	20.98	North Carolina.
Alder	1	120	....	Washington.
Spanish cedar	2	113	63.50	Kentucky, California.
Sassafras	9	62	....	Tennessee, Arkansas, North Carolina, Ohio.
Limber pine	2	55	14.00	Colorado, Wyoming.
Persimmon	8	38	24.48	Arkansas, Tennessee, South Carolina, Missouri.
Silverbell	2	35	....	North Carolina.
Hornbeam	7	29	24.70	New Hampshire, Pennsylvania, Michigan, New York.
Jenisero	1	5	....	California.
Holly	3	5	24.00	Alabama, North Carolina, South Carolina.
Osage orange	1	5	....	Oklahoma.

LATH.

Data on the production of lath were secured for 1915 and supply a gap existing in forest products statistics since 1912. The 1915 reported lath cut was 2,745,134,000, and it is estimated that the total cut was 3,250,000,000. Table 33 compares the 1915 and 1912 production of lath in the principal producing States. The number of active mills reporting each year, as well as the cut for each year, is given for the principal States. Lath are mostly manufactured by large sawmills. In both 1915 and 1912 reports were secured from practically all the large sawmills active, and the reported production of lath in the two years is therefore very close to the actual total. It follows then that, since the 1915 reported cut is greater than the 1912 reported cut and since only two-thirds as many mills reported in 1915 as in 1912, the production of lath increased from 1912 to 1915. This increase came in a poor lumber year; but the demand for lath has increased since 1912 largely because of stucco construction.

The reported total cut of lath for several years previous to 1912 was as follows: 1911, 2,971,110,000; 1910, 3,494,718,000; 1909, 3,703,-195,000.

TABLE 33.—*Reported production of lath, 1915 and 1912.*

[Computed total 1915 cut, 3,250,000 thousand.]

State.	Number of active mills reporting.		Quantity reported, thousands.	
	1915	1912	1915	1912
United States	1,689	2,586	2,745,134	2,719,163
Louisiana	66	65	418,554	330,474
Washington	71	69	389,995	336,538
Minnesota	54	74	230,686	269,095
Wisconsin	116	192	179,193	257,657
Maine	122	172	172,346	210,023
Michigan	74	135	124,543	173,415
Mississippi	29	22	123,011	81,315
Virginia	101	222	97,921	71,356
Arkansas	48	42	97,185	90,216
North Carolina	106	116	96,474	94,086
Oregon	28	32	95,801	131,734
Florida	23	26	89,860	51,078
Idaho	29	20	85,672	50,895
West Virginia	70	121	82,561	159,119
All other States (see Summary, p. 40)	752	1,278	461,332	412,162

SHINGLES.

Shingle production statistics, formerly secured annually, were omitted for 1913 and 1914, but were secured for 1915. Table 34 compares the 1915 cut with that for 1912. Both the cut of shingles and the number of mills reporting are shown, and the principal shingle-producing States listed. While many more mills reported for 1912 than for 1915, it is thought that the 1915 figures reflect conditions pretty accurately. Especially is the figure for Washington, which supplies 75 per cent, very close to the actual total cut. The data for Washington were secured by the Portland (Oreg.) district office of products, which is in close touch with the Washington shingle mills. Many small shingle mills in the eastern half of the country were not reached. However, figures were secured from practically all of the larger mills, and so the statistics are presumably correct in indicating a big drop in shingle production since 1912. As the table shows, the 1915 reported cut was 8,459,378,000, the estimated total 9,500,000,000, and the 1912 reported cut 12,037,685,000. The decrease is partly due to increased imports from British Columbia. The reported total figures for previous years are: 1911, 12,113,867,000; 1910, 12,976,362,000; 1909, 14,907,371,000.

TABLE 34.—*Reported production of shingles, 1915 and 1912.*

[Computed total 1915 cut, 9,500,000 thousand.]

State.	Number of active mills reporting.		Quantity reported, thousands.	
	1915	1912	1915	1912
United States	1,648	3,615	8,459,378	12,037,685
Washington	239	387	6,313,335	7,996,251
Louisiana	45	51	385,610	718,026
Oregon	48	66	336,652	271,205
Maine	187	277	268,004	393,772
Michigan	63	159	250,640	459,359
California	25	61	200,755	471,592
Wisconsin	77	159	122,882	267,945
Florida	31	76	116,054	309,081
North Carolina	125	303	74,773	196,943
Georgia	111	240	69,308	216,688
Alabama	82	78	67,629	126,205
Arkansas	31	184	20,501	114,458
All other States (see Summary, p. 40)	584	1,574	233,235	496,160

LUMBER VALUES.

Average or mill-run values, f. o. b. mill, have been compiled in connection with every lumber census since 1899 except for 1905, 1913, and 1914. The need of such data by the Government and the trade led to their collection for 1915.

Values for the principal woods in the most important States are given in preceding tables in this bulletin. Table 35 gives the average value of the same woods for all years for which such data are available. The prices for the years 1899 to 1910, inclusive, were compiled from replies made by the mills reporting production for those years; a great many mills are therefore represented. The values for 1911 were compiled from a former quarterly Forest Service publication, "Record of Wholesale Prices of Lumber," which was based on quarterly reports received from about 1,000 large mills throughout the United States and reports for the year from a special list of 5,000 mills. The 1912 values came entirely from the "Record of Wholesale Prices of Lumber." Since the larger mills ordinarily get better prices than the smaller establishments, the 1912 values in Table 35 are somewhat higher than the actual average values of lumber cut in that year. The 1915 values were compiled from replies received from about one-half of the mills reporting their cut. These mills were well distributed as to size and regions, and the results are therefore very representative but not absolute.

Since the values given in the bulletin are averages for 12 months for mills located at different points in each State, they should not be understood to be wholesale quotations f. o. b. any point at any particular time.

TABLE 35.—*Average value of lumber per thousand feet, board measure, by kinds of wood, for specified years, 1899 to 1915.*

Kind of wood.	1915	1912 [1]	1911	1910	1909	1908	1907	1906	1904	1899
All kinds	$14.04	$15.35	$15.05	$15.30	$15.38	$15.37	$16.56	$16.54	$12.76	$11.13
Softwoods:										
Yellow pine	12.41	14.36	13.87	13.29	12.69	12.66	14.02	15.02	9.96	8.46
Douglas fir	10.59	11.58	11.05	13.09	12.44	11.97	14.12	14.20	9.51	8.67
White pine	17.44	19.13	18.54	18.93	18.16	18.17	19.41	18.32	14.93	12.69
Hemlock	13.14	13.68	13.59	13.85	13.95	13.65	15.53	15.31	11.91	9 98
Spruce	16.58	17.02	16.14	16.62	16.91	16.25	17.26	17.33	14.03	11.27
Western yellow pine	14.32	13.62	13.88	14.26	15.39	15.03	15.67	14.01	11.30	9.70
Cypress	19.85	20.09	20.54	20.51	20.46	21.30	22.12	21.94	17.50	13.32
Redwood	13.54	14.13	13.99	15.52	14.80	15.66	17.70	16.64	12.83	10.12
Cedar	16.10	[2] 14.45	13.86	15.53	19.95	18.03	19.14	18.12	14.35	10.91
Larch (tamarack)	10.78	[3] 11.96	11.87	12.33	12.68	12.20	13.99	13.50	11.39	8.73
White fir	10.94	9.86	10.64	11.52	13.10	11.38	15.45	12.91	(4)	(4)
Sugar pine	17.40	(4)	17.52	18.68	18.14	17.78	19.84	16.11	(4)	12.30
Balsam fir	13.79	(4)	13.42	14.48	13.99	14.36	16.16	(4)	(4)	(4)
Lodgepole pine	13.57	(4)	12.41	14.88	16.25	(4)	(4)	(4)	(4)	(4)
Hardwoods:										
Oak	18.73	19.63	19.14	18.76	20.50	21.23	21.23	21.76	17.51	13.78
Maple	15.21	15.56	15.49	16.16	15.77	16.30	16.84	15.53	14.94	11.83
Red gum	12.54	12.60	12.11	12.26	13.20	13.08	14.10	13.46	10.87	9.63
Chestnut	16.17	16.62	16.63	16.23	16.12	16.27	17.04	17.49	13.78	13.37
Yellow poplar	22.45	24.06	25.46	24.71	25.39	25.30	24.91	24.21	18.99	14.03
Birch	16.52	17.43	16.61	17.37	16.95	16.42	17.37	17.24	15.44	12.50
Beech	14.01	13.51	14.09	14.34	13.25	13.50	14.30	14.05	(4)	(4)
Basswood	18.89	19.26	19.20	20.94	19.50	20.50	20.03	18.66	16.86	12.84
Elm	16.98	16.87	17.13	18.67	17.52	18.40	18.45	18.08	14.45	11.47
Ash	22.15	20.27	21.21	22.47	24.44	25.51	25.01	24.35	18.77	15.84
Cottonwood	17.36	[5] 20.44	18.12	17.78	18.05	17.76	18.42	17.15	14.92	10.37
Tupelo	12.25	13.61	12.46	12.14	11.87	13.36	14.48	14.13	(4)	(4)
Hickory	23.35	23.29	22.47	26.55	30.80	29.66	29.50	30.42	23.94	18.78
Walnut	48.47	(4)	31.70	34.91	42.79	42.53	43.31	42.25	45.64	36.49
Sycamore	13.86	(4)	13.16	14.10	14.77	14.67	14.58	(4)	(4)	11.04

1 1912 values based on limited number of reports.
2 Western red cedar only.
3 Western larch only.
4 Data not obtained.
5 Southern cottonwood only.

DETAILED SUMMARY.

Table 36 summarizes the figures in preceding tables, and in addition shows the amounts of each kind of wood cut in each State. Softwoods and hardwoods are separated in order to show the production by States of the two general kinds of lumber.

TABLE 36.—*Active sawmills (cutting 50 M and over) reporting, and reported production of each kind of lumber and lath and shingles, by States, 1915.*

State.	Number of active sawmills reporting.	Aggregate, M feet b. m.	Softwoods, in M feet b. m.														
			Total.	Yellow pine.	Douglas fir.	White pine.	Hemlock.	Western yellow pine.	Spruce.	Cypress.	Redwood.	Cedar.	Larch.	White fir.	Sugar pine.	Balsam fir.	Lodgepole pine.
United States	16,815	31,241,734	25,440,685	12,177,335	4,121,897	2,291,480	2,026,460	1,252,244	1,193,985	926,758	418,824	352,482	348,428	121,653	115,109	71,358	22,672
Alabama	659	1,128,381	1,027,523	1,023,306						3,803		414					
Arizona	14	75,915	75,913		70			75,843									
Arkansas	642	1,571,662	1,107,538	1,082,155						25,383							
California [1]	[1] 136	[1] 1,119,458	[1] 1,118,279		117,951		4,537	[2] 389,991	9,477		418,824	12,185		[1] 50,820	114,494		
Colorado	132	69,852	69,719		5,366			37,241	16,386					926			9,800
Connecticut	108	52,398	12,097	55		8,817	3,209					16					
Delaware	37	14,402	8,705	8,670								35					
Florida	193	1,004,170	992,110	830,815						161,123		172					
Georgia	579	636,547	580,134	525,747		3,144	1,500			49,703		40					
Idaho	203	770,031	768,991		76,283	301,600	1,345	201,858	2,946			29,654	111,345	42,906			1,054
Illinois	131	49,960	2,078	126						1,952							
Indiana	354	198,154	79	13		11						50	5				
Iowa	78	18,035	13			11						1					
Kentucky	616	399,761	39,473	12,909		5,896	18,041		15	1,526		1,086					
Louisiana	302	3,669,641	3,442,366	2,881,615						560,751							
Maine	607	805,981	756,098	200		270,581	69,568		362,704			15,700	66			37,279	
Maryland	200	90,297	37,404	25,625		1,949	9,698			90		42					
Massachusetts	259	201,921	168.733	4,955		106,824	21,671		34,389			738	2			154	
Michigan	346	1,032,154	482,279			64,267	372,512		10,358			8,283	22,368			4,491	
Minnesota	217	1,021,568	980,348			869,574	25		58,472			220	37,898			14,159	
Mississippi	627	1,957,899	1,681,551	1,657,887						23,656		8					
Missouri	420	253,802	74,408	50,421						23,986		1					
Montana	94	324,333	324,175		41,464	27,330		118,920	13,266				115,001	6,510			1,684
New Hampshire	319	388,995	345,819	115		189,645	39,262		112,904			104	84			3,705	
New Jersey	181	42,619	11,822	8,964		87	132		30			2,604	5				
New Mexico	43	65,787	65,787		3,767			61,466	522					32			
New York	1,247	381,208	207,586	340		60,576	93,008		53,185			242	16			219	
North Carolina	1,348	1,537,134	1,309,502	1,130,144		16,647	46,546		83,601	27,059		5,505					
Ohio	720	281,630	2,863			449	2,389						25				
Oklahoma	105	173,374	161,951	161,951													
Oregon	363	1,505,633	1,505,058		1,119,395	622	61,963	189,203	65,327			39,835	15,506	12,592	615		
Pennsylvania	1,032	622,897	307,388	6,416		39,181	259,914		1,757			6	64			50	
Rhode Island	12	10,504	3,994			3,584	400					10					
South Carolina	389	673,270	623,603	592,184		451	100			30,062		806					
South Dakota	30	22,562	22,457					22,457									
Tennessee	808	477,975	87,005	48,523		3,855	23,252		335	7,220		3,495	325				

Texas	264	1,618,565	1,558,459	1,557,270	....	....	....	....	....	1,188	......	1	......	......	......	......	......
Utah	73	10,892	10,820	....	1,325	....	....	4,100	3,282	......	......	......	......	726	......	......	1,387
Vermont	338	198,319	123,542	....	....	15,040	29,589	....	69,134	......	......	920	10	......	......	8,849	......
Virginia	1,245	919,493	627,275	562,926	....	5,934	25,935	....	1,230	9,256	......	21,994	......	......	......	......	......
Washington	389	3,726,343	3,725,812	....	2,754,179	90,240	306,570	148,789	196,203	......	......	201,561	21,477	6,783	......	......	10
West Virginia	510	967,304	270,645	4,003	....	13,859	160,923	....	91,780	......	......	75	......	......	......	5	......
Wisconsin	383	1,135,740	704,116	....	....	191,306	474,371	....	5,083	......	......	6,679	24,231	......	......	2,446	......
Wyoming	62	15,168	15,167	....	2,097	....	....	2,376	1,599	......	......	......	......	358	......	......	8,737

[1] Includes 2 mills in Nevada.

[2] Includes 1 mill in Nevada.

TABLE 36.—*Active sawmills (cutting 50 M and over) reporting, and reported production of each kind of lumber and lath and shingles, by States, 1915*—Continued.

State.	Hardwoods, in M feet b. m.																	Lath, thousands (1,689 mills reporting).	Shingles, thousands (1,648 mills reporting).
	Total.	Oak.	Maple.	Red gum.	Chestnut.	Yellow poplar.	Birch.	Beech.	Basswood.	Elm.	Ash.	Tupelo.	Cottonwood.	Hickory.	Walnut.	Sycamore.	Minor species.		
United States	5,801,049	2,070,444	771,223	478,099	399,473	377,386	355,328	303,835	207,607	177,748	159,910	153,001	138,282	86,015	65,144	19,729	37,825	2,745,134	8,459,378
Alabama	100,858	37,088	880	18,829	165	22,808	2	620	140	247	1,736	14,546	2,204	1,019	220	225	129	59,570	67,629
Arizona	2	2																23,293	200
Arkansas	464,124	223,752	4,144	153,091		396		65	36	17,055	18,957	3,595	23,389	13,443	511	4,645	1,045	97,185	20,501
California	1,179	802					120										257	38,284	200,755
Colorado	133												79				154	8,003	61
Connecticut	40,301	9,686	369		27,351	465	567	335	111	69	441	10	89	753	27	26	2	343	833
Delaware	5,697	4,264	338	400	305	226	10	29			2	50		70	3			400	25
Florida	12,060	758		4,127		1,453	8				2,163	1,499	1,932	114		6		89,860	116,054
Georgia	56,413	20,467	236	5,927	4,743	20,343	61	152	115	271	2,605	589	211	411	133	149		34,969	69,308
Idaho	1,040												1,040					85,672	49,512
Illinois	47,882	22,660	1,917	3,099	3	545	125	775	51	2,780	2,520	4,088	733	929	7,077	559	21	384	
Indiana	198,075	80,289	15,662	8,106	508	5,812	328	31,316	4,122	15,129	11,006	1,148	869	7,150	11,267	3,309	2,054	391	270
Iowa	18,022	5,385	623				148		1,754	2,161	234		2,855	293	4,439	100	30		100
Kentucky	360,288	222,964	4,987	6,966	15,508	49,154	655	20,578	4,979	2,358	6,966	5,198	1,532	8,708	4,007	1,678	4,050	12,588	6,835
Louisiana	227,275	74,304	306	39,540		550		54	830	6,031	14,602	62,402	17,121	3,770		195	7,570	418,554	385,610
Maine	49,883	8,067	4,746				27,138	4,317	1,941	517	1,584		1,563	10				172,346	268,004
Maryland	52,893	24,348	4,813	1,703	14,191	2,301	1,150	1,284	1,236	38	225	565	169	503	89	271	7	12,877	430
Massachusetts	33,188	6,537	3,296		15,138	306	3,371	2,789	369	67	883	25	249	127	21		10	558	1,832
Michigan	549,875	6,384	339,618			208	56,869	65,998	28,718	35,598	7,839		8,188	259	43	104	49	124,543	250,640
Minnesota	41,220	8,974	891				6,289	30	4,939	3,754	2,264		14,074	4	1			230,686	8,041
Mississippi	276,348	89,469	1,265	110,285	2	6,173		455	150	4,857	7,381	7,844	37,139	3,220	15	333	7,760	123,011	11,950
Missouri	179,394	95,435	5,769	28,345		666	142	16	102	8,817	5,258	5,822	3,648	5,236	17,954	2,144	40	9,855	3,820
Montana	158												158					27,334	10,280
New Hampshire	43,176	8,881	8,122		4,233		13,629	6,016	726	54	1,090		363	22	10		30	24,663	5,936
New Jersey	30,797	13,155	488	875	13,301	683	100	260	25	244	318	154	26	1,117	27	22	2	9,482	17,269
New Mexico																		2,992	181
New York	173,622	21,617	45,407		13,425	86	20,949	32,689	18,114	9,435	7,163	14	1,109	1,110	20	87	2,397	15,111	5,247
North Carolina	227,632	97,014	5,469	14,831	40,876	33,168	2,322	1,637	6,129	314	3,423	16,758	989	1,760	249	245	2,448	96,474	74,773
Ohio	278,767	128,562	32,255	643	8,472	29,175	545	31,923	7,914	13,815	8,616	404	974	6,851	6,917	1,522	179	4,717	25
Oklahoma	11,423	7,818	36	835			1		100	434	879		598	233	187	237	65	11,176	890
Oregon	575	50	190								100		235					95,801	336,652
Pennsylvania	315,509	125,581	52,316	648	54,388	5,732	11,771	43,168	8,075	1,155	5,625	481	213	4,453	504	95	1,304	70,877	8,064
Rhode Island	6,510	1,553	245		4,553	15	50	25			49		5	15					400

South Carolina	49,667	7,253	937	21,821	......	9,230	......	75	......	234	1,775	7,922	101	102	10	203	4	13,350	11,854
South Dakota	105	......	......	......	......	......	......	......	......	......	......	......	105	......	......	......	......	7,292	436
Tennessee	390,970	210,965	7,498	24,729	28,484	46,129	1,168	6,556	4,668	7,825	15,233	1,149	10,466	11,933	9,123	2,739	2,305	24,510	7,912
Texas	60,106	32,564	1	18,003	......	......	45	......	47	513	4,690	930	1,365	1,343	49	291	265	40,698	22,245
Utah	72	......	......	......	......	......	......	......	......	......	......	......	72	......	......	......	......	744	920
Vermont	74,777	3,285	22,119	......	265	......	27,352	9,162	6,200	1,003	3,188	......	2,103	33	14	......	53	6,290	6,388
Virginia	292,218	165,592	7,180	13,255	35,573	40,899	845	2,321	5,131	148	1,371	15,832	508	1,627	719	294	923	97,921	49,758
Washington	531	......	150	......	......	......	......	......	......	......	80	......	181	......	......	......	120	389,995	6,313,335
West Virginia	696,659	291,261	76,934	2,041	117,989	100,863	17,715	38,952	26,956	291	5,911	1,976	141	9,372	1,477	250	4,530	82,561	736
Wisconsin	431,624	13,658	122,016	......	......	......	161,853	2,238	73,929	42,534	13,733	......	1,486	25	31	......	121	179,193	122,882
Wyoming	1	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	[1] 1	581	785

[1] Limber pine.

APPENDIX.

THE PRODUCTION OF LUMBER IN 1914.

Since no bulletin dealing with the 1914 lumber cut has been issued, a summary table similar to the preceding is included in this bulletin in order to make the detailed 1914 figures available to the public.

TABLE 37.—*Number of active sawmills (cutting 50 M and over) reporting and quantity of lumber reported by States and kinds of wood, 1914.*

State.	Number of active sawmills reporting.	Total cut, in M feet b. m.	Softwoods, in M feet b. m.													
			Total softwoods.	Yellow pine (12,054 mills).	Douglas fir (1,067 mills).	White pine (4,541 mills).	Hemlock (4,538 mills).	Western yellow pine (846 mills).	Spruce (2,165 mills).	Cypress (670 mills).	Redwood (55 mills).	Cedar (653 mills).	Larch (530 mills).	Sugar pine (54 mills).	Balsam fir (703 mills).	White fir (126 mills).	Lodgepole pine (104 mills).
United States	27,506	37,346,023	29,406,839	14,472,804	4,763,693	2,632,587	2,165,728	1,327,365	1,245,614	1,013,013	535,199	499,903	358,561	136,159	125,212	112,627	18,374
Alabama	1,327	1,494,732	1,345,188	1,337,710						5,604		1,874					
Arizona	13	78,667	78,667					78,667									
Arkansas	1,110	1,796,780	1,224,025	1,189,033						34,992							
California	175	1,303,183	1,299,725		142,910		5,153	409,953	10,857		535,199	17,872		132,368		45,413	
Colorado	145	102,117	101,984		7,951			65,117	21,302							423	7,191
Connecticut	198	81,883	15,425	522		10,604	4,264					35					
Delaware	74	25,517	19,189	19,174						10		5					
Florida	381	1,073,821	1,062,551	942,231						119,820		500					
Georgia	1,394	1,026,191	948,130	893,316		4,244	1,417			49,153							
Idaho	140	763,508	763,465		96,323	280,608	11,891	159,839	369			61,041	108,793			43,860	741
Illinois	210	66,227	3,889	307		250				3,332							
Indiana	650	298,571	212	68						142			2				
Iowa	30	11,443	20			20											
Kentucky	1,281	596,392	45,318	30,416		1,299	11,899		44	1,067		593					
Louisiana	428	3,956,434	3,643,066	2,970,855						672,211							
Maine	879	992,594	942,919	3,209		315,306	106,137		399,126			47,375	26		71,740		
Maryland	397	162,097	73,970	57,679		517	14,524			1,241		9					
Massachusetts	235	143,094	108,166	1,139		65,589	13,726		26,518			992			202		
Michigan	428	1,214,435	576,446			91,487	416,131		23,417			7,724	26,787		10,900		
Minnesota	286	1,312,230	1,258,634			1,108,021	300		68,325			459	53,131		28,398		
Mississippi	1,212	2,280,966	1,895,535	1,865,740						29,795							
Missouri	686	370,571	90,864	55,643						35,221							
Montana	124	317,842	317,750		51,061	17,537		134,568	7,666			1,005	101,771			465	3,677
New Hampshire	461	482,744	428,882	3,528		265,188	47,224		108,173			272	16		4,481		
New Jersey	138	48,748	23,601	13,140		26	280					10,155					

New Mexico	36	57,167	57,167		1,145			54,728	1,294								
New York	1,440	486,195	236,332			72,110	107,475		55,823			640	27		257		
North Carolina	2,824	2,227,854	1,865,854	1,715,158		23,885	40,030		64,828	16,940		4,983			30		
Ohio	787	286,063	2,499	1,825		140	534										
Oklahoma	228	200,594	161,020	161,020													
Oregon	408	1,817,875	1,809,336		1,435,073	796	45,192	210,438	63,488			23,706	11,763	3,791		15,072	17
Pennsylvania	1,755	864,710	344,026	15,564		71,215	256,130		1,114			2			1		
Rhode Island	28	15,902	6,358	2,150		4,020	65		120			3					
South Carolina	728	701,540	631,570	606,891		400	565			23,714							
South Dakota	32	18,744	18,744					18,744									
Tennessee	1,830	885,035	164,776	100,872		9,758	35,551		1,903	9,089		7,603					
Texas	365	1,554,005	1,511,700	1,500,577						2,112		11					
Utah	67	8,680	8,460		326			5,056	1,069							867	1,142
Vermont	462	249,608	150,572	70		15,435	42,119		84,870			834	58		7,186		
Virginia	2,159	1,488,070	1,027,166	961,521		12,714	31,226		330	8,570		12,805					
Washington	512	3,946,189	3,944,373		3,027,994	26,958	207,459	175,426	189,277			294,284	19,502			3,473	
West Virginia	913	1,118,480	308,171	14,446		10,991	175,952		106,782								
Wisconsin	467	1,391,001	864,360			223,433	590,484		6,692			5,049	36,685		2,017		
Wyoming	56	11,852	11,852		910	36		2,743	2,227							330	5,606
All other States[1]	7	15,672	14,882					12,086				72				2,724	

[1] Includes Kansas, Nebraska, and Nevada.

TABLE 37.—*Number of active sawmills (cutting 50 M and over) reporting and quantity of lumber reported by States and kinds of wood, 1914.*—Contd.

State.	Hardwoods, in M feet, b. m.																
	Total.	Oak (15,352 mills).	Maple (5,006 mills).	Red gum (2,229 mills).	Chestnut, (4,387 mills).	Yellow poplar (4,859 mills).	Birch (2,593 mills).	Beech (3,923 mills).	Basswood (3,130 mills).	Elm (2,665 mills).	Cottonwood (1,019 mills).	Ash (3,649 mills).	Tupelo (231 mills).	Hickory (2,448 mills).	Walnut. (749 mills).	Sycamore (603 mills).	Minor species, M feet b. m.
United States	7,939,184	3,278,908	909,743	675,380	540,591	519,221	430,667	376,464	264,656	214,294	195,198	189,499	124,480	116,113	25,573	22,773	55,624
Alabama	149,544	79,057	476	26,818	334	20,981	4	178	275	571	3,145	1,917	12,870	2,489	82	117	230
Arkansas	572,755	292,040	2,328	190,008		160	2		11	16,141	27,571	18,172	1,871	20,217	140	3,404	690
California	3,458	2,790					500				74						94
Colorado	133										133						
Connecticut	66,458	13,466	678		47,801	770	643	502	170	45	70	1,057	3	994	115	1	143
Delaware	6,328	5,060	252	540	112	101	8	1		5		5	2	210	7	25	
Florida	11,270	519		2,141		1,062					1,387	964	1,603	1,532			2,062
Georgia	78,061	35,779	216	13,070	3,631	19,878	10	162	60	422	115	2,437	1,300	506		376	99
Idaho	43										43						
Illinois	62,338	33,711	2,802	4,321	7	1,325	1	841	19	5,375	2,724	6,017	46	1,875	1,497	1,674	103
Indiana	298,350	132,260	29,341	9,132	542	11,071	88	51,779	5,268	22,507	1,472	11,014	1,129	10,110	4,626	3,803	4,217
Iowa	11,423	2,316	509				30		574	646	1,948	100		319	4,974	5	2
Kentucky	551,074	370,135	6,457	14,321	20,372	72,523	624	23,669	8,692	1,178	1,884	5,622	307	11,633	1,754	2,693	9,210
Louisiana	313,368	88,619		54,176		194		12	30	3,752	36,003	19,515	95,283	6,426	12	281	9,065
Maine	49,675	10,647	7,076				22,746	3,231	1,980	106	1,917	1,972					
Maryland	88,127	44,537	5,884	4,823	23,429	4,611	1,214	1,372	692	36		178	62	640	45	391	212
Massachusetts	34,928	4,786	5,185		13,140		4,307	4,262	946	58	378	1,361		60	50		395
Michigan	637,989	9,707	370,271			44	84,342	70,337	43,568	41,790	8,364	8,893		219	92	34	328
Minnesota	53,596	7,793	599				6,854		9,685	4,259	22,395	2,009					2
Mississippi	385,431	154,822	847	143,542		15,939		586	1	4,646	43,283	8,086	1,877	8,433		129	3,240
Missouri	279,707	173,325	6,942	51,600		267	303	102	171	16,736	11,915	6,204	1,873	3,158	4,561	2,229	321
Montana	92										92						
New Hampshire	53,862	16,644	8,613		4,180		16,713	5,438	702	34	382	1,155					1
New Jersey	25,147	10,432	367	736	11,515	1,037	79	99		45		274	30	432	51		50
New York	249,863	26,717	76,544	29	16,371	71	29,669	45,461	24,370	12,776	1,574	11,534	49	1,145	7	74	3,472
North Carolina	362,000	184,898	5,121	43,602	54,105	49,751	2,400	1,541	7,447	10		6,401	431	2,414	151	324	3,404
Ohio	283,564	134,709	36,834	2,142	6,016	18,187	299	35,553	7,288	14,411	606	10,717	948	8,684	3,153	1,529	2,488
Oklahoma	39,574	29,221	75	720					5	681	4,360	2,008		611	38	1,178	677
Oregon	8,539	6,201	1,114								339	809					76
Pennsylvania	520,684	233,667	70,212	388	115,396	10,728	13,903	49,137	8,324	1,183	739	6,980	47	5,652	351	119	3,858
Rhode Island	9,544	2,034	228		6,815			25				410			32		
South Carolina	69,970	16,270	363	35,444	413	11,793		10		306	106	1,992	2,827	251	1	192	2
Tennessee	720,259	440,746	6,455	46,724	44,178	93,241	1,350	11,919	7,257	13,764	8,289	18,837	262	17,002	2,852	3,744	3,639
Texas	42,305	25,776		6,724				3		450	4,892	3,845	50	113			4 2

Utah	220	......	......	......	......	......	......	......	......	......	200	......	......	......	......	......	20
Vermont	99,036	3,258	34,184	......	65	......	33,872	15,797	5,273	568	1,498	4,428	......	......	10	......	83
Virginia	460,904	292,546	5,701	17,637	60,374	65,777	968	2,766	7,779	75	1	2,681	1,019	1,355	263	299	1,663
Washington	1,816	......	330	......	......	......	......	......	......	......	1,085	75	......	......	......	......	326
West Virginia	810,309	378,745	67,376	6,742	111,795	119,710	19,270	47,424	31,992	43	4,887	6,520	591	9,601	702	152	4,7[illegible]9
Wisconsin	526,641	15,440	156,363	......	......	......	190,468	4,257	92,077	51,640	812	15,310	......	27	7	......	240
All other States [1]	790	235	......	......	......	......	......	......	......	35	515	......	......	5	......	......	......

[1] Includes Kansas and Nebraska.

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STUDIES ON THE DIGESTIBILITY OF SOME ANIMAL FATS.

By C. F. LANGWORTHY, *Chief*, and A. D. HOLMES, *Scientific Assistant, Office of Home Economics.*

CONTENTS.

INTRODUCTION.

Previous papers[1] reported the results of experiments undertaken to determine the thoroughness of digestion of lard, beef fat, mutton fat, butter, olive oil, cottonseed oil, peanut oil, coconut oil, sesame oil, and cocoa butter, which showed that fairly large quantities of these fats incorporated in a simple mixed diet could be eaten without digestive disturbances and that all were well digested, the coefficient of digestibility being proportional to the melting point of the fat. In continuation of the study of animal and vegetable fats and their dietetic uses, this bulletin reports a study of the digestibility of chicken fat, goose fat, brisket fat, cream, fat in egg yolk, and fat or oil in fish.

Fats are so very similar in their chemical nature that it is natural to assume that they would not differ materially with respect to their food value (of which digestibility is an important factor) under comparable conditions. While race experience would indicate that this is true in the main, there is reason to believe that the question of the digestibility of fats and the closely related matter of the energy which they supply to the body merit further study. That the digestion of different sorts is not alike in all its steps is indicated

[1] U. S. Dept. Agr. Buls. 310 (1915); 505 (1917).

NOTE.—This bulletin records studies of the digestibility of chicken fat, goose fat, brisket fat, cream, fat in egg yolk, and fat or oil in fish. It is primarily of interest to students and investigators of food problems.

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by the work of Tangl and Erdélyi[1] and of Von Fejér,[2] who have observed that fats with a melting point somewhat higher than normal body temperature do not leave the stomach so readily as those of a lower melting point, and, furthermore, that they are not so easily emulsified in the intestine. Apparently no connection has been shown between these observations and thoroughness of digestion. Before one can assume that the fuel value of fat, or more accurately the fuel value of digested fat, actually represents its energy value to the body, one must take into account such work as that of Lusk[3] and his associates, which showed that the digestion and assimilation of foods (including fat) caused an increased output of energy, not ascribable to muscular work, and designated specific-dynamic effect. The test reported did not compare different fats.

That in comparing fats we must consider not alone such questions of thoroughness of digestion and energy expenditure as a result of digestion and their relation to nutrition is apparent from recent work of McCollum and Davis[4] and Osborne and Mendel,[5] who concluded that certain fats carry either as an integral part or as a complement a small amount of substance important in growth. In discussing dietetics, it is commonly assumed that fat and carbohydrates can replace each other as sources of energy in proportion to their theoretical energy values. There are times when it is not wise to do this, at least under pathological conditions, as recent work would indicate, since, according to Ringer,[6] there is a limit beyond which this replacement can not go without serious results, some carbohydrate, it is claimed, being essential for the complete combustion of fat.

EXPERIMENTAL METHODS.

The investigations here reported form a part of a series of studies of the thoroughness of digestion of culinary and table fats of animal and vegetable origin, including those eaten as such, those added to foods in cookery, and those which form an integral part of the foods in which they naturally occur. In all the same general procedure was followed.

The experimental methods were those adopted in earlier work[7] carried on by the department as a part of its investigations of the nutritive value of foods as a result of extended studies of the advantages and disadvantages of differences in technique and in laboratory methods.

The subjects were young men (medical or dental students) in good health, of similar occupation and muscular activity. The diets

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[1] Biochem. Ztschr., 34 (1911), No. 1-2, pp. 94-110.
[2] Idem, 53 (1913), No. 1-2, pp. 168-178.
[3] Jour. Biol. Chem., 22 (1915), No. 1, pp. 15-41; Cornell Univ. Med. Bul., 5 (1915), No. 2 (pt. 1, paper 14).
[4] Jour. Biol. Chem., 15 (1913), No. 1, pp. 167-175.
[5] Idem, 16 (1913), No. 3, pp. 423-437; 17 (1914), No. 3, pp. 401-408.
[6] Idem, 17 (1914), No. 2, pp. 107-119.
[7] U. S. Dept. Agr., Office Expt. Stas. Bul. 143 (1904), pp. 57-77.

were simple, the fat-containing food, which was the principal item, being supplemented in each case by carbohydrate foods (such as biscuits or crackers, and mashed potato), fruit (oranges or apples), and tea or coffee with sugar, if a beverage besides water was desired. The subjects were not required to eat like quantities of the food supplying the fat, or of the other foods, but in every case they were expected to eat an amount of fat which would supply about 30 per cent of the total energy value of the ration, this being the quantity which fat contributes to the average American and European diet, as shown by a compilation of data made for this study. With the experimental diets chosen this would mean about 100 grams of fat. Special pains were always taken to use fat which was not rancid, since Adler,[1] on the basis of experimental data, has attributed a hemolytic action to the presence of free fatty acids in foods.

In making up the diets for the experiments a stiff cornstarch pudding or blancmange (heavily flavored with caramel to mask any distinctive fat flavor) was used as a vehicle for the separated fats. The same sort of blancmange was also used in the experiments with cream and egg yolk. For the study of fish oil a typical fat fish was used as the source of the fat.

In these, as in the earlier digestion experiments reported, the three-day or nine-meal test period proved entirely satisfactory. The test periods were followed by rest periods of four days, in which the subjects were permitted to eat whatever they desired. Obviously, the diet during the experimental periods was limited to the prescribed ration. In every case weighed portions of the different foods were prepared in advance for each meal for each subject and the subjects were instructed to reserve any uneaten portions of the diet for weighing, in order that the exact amount eaten might be ascertained. They were also instructed to observe due care in the collection and separation of the feces pertaining to an experimental period.

The records of the experiments include data for the amounts of food eaten and for the feces. Samples of both food and feces were analyzed to determine what percentages of protein and carbohydrate as well as fat were available to the body.

The percentage of fat in the feces was determined by ether extraction of the air-dried sample for 18 to 20 hours by the Soxhlet method, as described by the Association of Official Agricultural Chemists.[2] It is recognized that by this method some fat in the form of soaps may not be extracted. However, comparative tests by the Folin-Wentworth[3] method and the Soxhlet method, made as a part of the digestion work of this office, have given results that are not uniform and are not significant from the standpoint of dietetics.

The ether extract obtained by the method followed is assumed to represent the fat of undigested food, and this quantity less the pro-

[1] Jour. Med. Research, 28 (1913), No. 1, pp. 199-226. [2] U. S. Dept. Agr., Bur. Chem. Bul. 107 (1912).
[3] Jour. Biol. Chem., 7 (1910), No. 6, pp. 424, 425.

portion ascribable to the fat supplied by the basal ration to represent the undigested portion of the fat studied. The significance of such values, in discussing problems of dietetics and the theoretical and other considerations having to do with metabolic products in feces, are fully discussed in earlier publications.[1]

DIGESTION EXPERIMENTS.

CHICKEN FAT.

Although chicken fat as such is not avaliable in quantity in most markets the very large demand for poultry, especially mature poultry, would indicate a very considerable consumption of the fat along with the chicken meat. Little information, however, as to its digestibility and nutritive value has been found in a survey of the literature. In studies of the digestibility of fish and poultry, Milner[2] found that chicken fat eaten as an integral part of poultry in a simple mixed diet was 97 per cent digested.

Several pounds of chicken fat, which had been taken in small quantities from fat birds drawn at the market for those not desiring the excess fat, were procured. It was passed through an ordinary meat grinder and heated in a double boiler to a temperature higher than its melting point, after which the fat was easily separated from surrounding tissues by straining.

For use in the digestion experiments the product was thoroughly mixed and incorporated in a blancmange or cornstarch pudding in the way previously described. Eight experiments of three days' duration were completed in which four normal subjects assisted. The results of these tests are recorded in the following tables:

Data of digestion experiments with chicken fat in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 274, subject H. F. B.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing chicken fat	2,357.0	1,072.0	45.7	359.7	863.6	16.0
Wheat biscuit	545.0	49.0	57.8	8.2	421.3	8.7
Fruit	1,549.0	1,346.1	12.4	3.1	179.7	7.7
Sugar	192.0				192.0	
Total food consumed	4,643.0	2,467.1	115.9	371.0	1,656.6	32.4
Feces	148.0		44.4	26.4	65.0	12.2
Amount utilized			71.5	344.6	1,591.6	20.2
Per cent utilized			61.7	92.9	96.1	62.3
Experiment No. 275, subject D. G. G.:						
Blancmange containing chicken fat	1,597.0	726.3	31.0	243.7	585.1	10.9
Wheat biscuit	396.0	35.7	42.0	5.9	306.1	6.3
Fruit	492.0	427.5	3.9	1.0	57.1	2.5
Sugar	158.0				158.0	
Total food consumed	2,643.0	1,189.5	76.9	250.6	1,106.3	19.7
Feces	88.0		26.2	15.6	40.1	6.1
Amount utilized			50.7	235.0	1,066.2	13.6
Per cent utilized			65.9	93.8	96.4	69.0

[1] U. S. Dept. Agr., Office Expt. Stas. Buls 126 (1903), pp. 18-20; 193 (1907), pp. 47-59; Connecticut Storrs Sta. Rpt. 1896, pp. 178-180.

[2] Connecticut Storrs Sta. Rpt. 1905, pp. 135, 136.

Data of digestion experiments with chicken fat in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Experiment No. 276, subject R. L. S.:						
Blancmange containing chicken fat	2,073.0	942.8	40.2	316.3	759.6	14.1
Wheat biscuit	340.0	30.6	36.0	5.1	262.8	5.5
Fruit	946.0	822.1	7.6	1.9	109.7	4.7
Sugar	43.0	....	....	....	43.0	....
Total food consumed	3,402.0	1,795.5	83.8	323.3	1,175.1	24.3
Feces	68.0	....	20.7	17.5	24.0	5.8
Amount utilized	....	....	63.1	305.8	1,151.1	18.5
Per cent utilized	....	....	75.3	94.6	98.0	76.1
Experiment No. 277, subject O. E. S.:						
Blancmange containing chicken fat	2,380.0	1,082.4	46.2	363.2	872.0	16.2
Wheat biscuit	450.0	40.5	47.7	6.7	347.9	7.2
Fruit	1,505.0	1,307.9	12.0	3.0	174.6	7.5
Sugar	171.0	....	....	....	171.0	....
Total food consumed	4,506.0	2,430.8	105.9	372.9	1,565.5	30.9
Feces	124.0	....	36.7	29.9	46.3	11.1
Amount utilized	....	....	69.2	343.0	1,519.2	19.8
Per cent utilized	....	....	65.3	92.0	97.0	64.1
Experiment No. 290, subject H. F. B.:						
Blancmange containing chicken fat	1,983.0	903.7	37.2	299.4	726.2	16.5
Wheat biscuit	499.0	44.9	52.9	7.5	385.7	8.0
Fruit	1,319.0	1,146.2	10.6	2.6	153.0	6.6
Sugar	127.0	....	....	....	127.0	....
Total food consumed	3,928.0	2,094.8	100.7	309.5	1,391.9	31.1
Feces	130.0	....	37.6	23.9	55.4	13.1
Amount utilized	....	....	63.1	285.6	1,336.5	18.0
Per cent utilized	....	....	62.7	92.3	96.0	57.9
Experiment No. 291, subject D. G. G.:						
Blancmange containing chicken fat	1,250.0	569.6	23.5	188.7	457.8	10.4
Wheat biscuit	480.0	43.2	50.9	7.2	371.0	7.7
Fruit	636.0	552.7	5.1	1.2	73.8	3.2
Sugar	156.0	....	....	....	156.0	....
Total food consumed	2,522.0	1,165.5	79.5	197.1	1,058.6	21.3
Feces	77.0	....	23.9	12.0	32.0	9.1
Amount utilized	....	....	55.6	185.1	1,026.6	12.2
Per cent utilized	....	....	69.9	93.9	97.0	57.3
Experiment No. 292, subject R. L. S.:						
Blancmange containing chicken fat	1,706.0	777.4	32.1	257.6	624.7	14.2
Wheat biscuit	413.0	37.2	43.8	6.2	319.2	6.6
Fruit	646.0	561.4	5.2	1.3	74.9	3.2
Sugar	54.0	....	....	....	54.0	....
Total food consumed	2,819.0	1,376.0	81.1	265.1	1,072.8	24.0
Feces	66.0	....	19.5	12.4	27.3	6.8
Amount utilized	....	....	61.6	252.7	1,045.5	17.2
Per cent utilized	....	....	76.0	95.3	97.5	71.7
Experiment No. 293, subject O. E. S.:						
Blancmange containing chicken fat	1,708.0	778.3	32.1	257.9	625.5	14.2
Wheat biscuit	411.0	37.0	43.6	6.1	317.7	6.6
Fruit	1,273.0	1,106.2	10.2	2.5	147.7	6.4
Sugar	171.0	....	....	....	171.0	....
Total food consumed	3,563.0	1,921.5	85.9	266.5	1,261.9	27.2
Feces	89.0	....	26.3	20.7	33.1	8.9
Amount utilized	....	....	59.6	245.8	1,228.8	18.3
Per cent utilized	....	....	69.4	92.2	97.4	67.3
Average food consumed per subject per day	1,167.8	601.7	30.4	98.2	428.7	8.8

Summary of digestion experiments with chicken fat in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
274	H. F. B	61.7	92.9	96.1	62.3
275	D. G. G	65.9	93.8	96.4	69.0
276	R. L. S	75.3	94.6	98.0	76.1
277	O. E. S	65.3	92.0	97.0	64.1
290	H. F. B	62.7	92.3	96.0	57.9
291	D. G. G	69.9	93.9	97.0	57.3
292	R. L. S	76.0	95.3	97.5	71.7
293	O. E. S	69.4	92.2	97.4	67.3
	Average	68.3	93.4	96.9	65.7

The average coefficient of digestibility of the total fat eaten during these tests was 93.4 per cent. As the ether extract of the feces, however, is known to contain metabolic product and undigested fat from the basal ration, which though nearly so was not absolutely fat free, a correction has been applied in the case of this fat and the others studied to determine the average digestibility of total fat consumed. Digestion experiments with the basal ration as the only source of fat have been reported in connection with the earlier animal fat experiments, from which it was concluded that 9.89 per cent of the total weight of water-free feces is made up of metabolic products and undigested fat from the food,[1] which latter must have been an insignificant quantity, since the total amount in the diet was so small. Subtracting the quantity represented by this percentage from the total ether extract of the feces, a value is obtained more nearly representing the weight of unutilized fat. The corrected value for the digestibility of fat then becomes 96.7 per cent.

GOOSE FAT.

In the United States goose fat is used as such only to a very limited extent and chiefly among those of foreign birth or parentage who adhere to special food customs.

Owing to the impossibility of obtaining goose fat in quantity from local dealers, an unusually fat or "stall-fed" goose was purchased. It weighed 27.5 pounds, 13 pounds of fat being obtained when the fat was cut away from the flesh and rendered in the usual way. The goose fat, which at room temperature (about 20° C.) is a soft, pale-yellow, granular solid, tended to separate into two layers on standing—an upper, oily layer, and a lower, more or less solid layer. By using freshly rendered fat, rancidity was avoided, which is likely to occur on keeping, perhaps owing to the 0.7 to 3.5 per cent of soluble fatty acid which the fat contains.

As regards previous work with this fat, Arnschink[2] conducted an experiment of four days' duration with a dog weighing 8 kilograms, in which an average of 50 grams, containing 70 per cent of oleic

[1] U. S. Dept. Agr. Bul. 310 (1915), p. 20.

[2] Ztschr. Biol., 8 (1890), pp. 443, 444.

acid and a relatively large amount of free fatty acids was eaten daily and 97.51 per cent digested. So far as can be ascertained, no experiments with human subjects have been recorded. In the work here reported a series of seven digestion experiments has been completed, the essential data of which are given below.

Data of digestion experiments with goose fat in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Experiment No. 209, subject O. E. S.:						
Blancmange containing goose fat	1,993.0	940.7	36.7	212.2	789.2	14.2
Wheat biscuit	162.0	14.6	17.2	2.4	125.2	2.6
Fruit	1,735.0	1,507.7	13.9	3.5	201.2	8.7
Sugar	206.0	....	....	....	206.0	....
Total food consumed	4,096.0	2,463.0	67.8	218.1	1,321.6	25.5
Feces	71.0	....	18.6	9.7	36.9	5.8
Amount utilized	....	....	49.2	208.4	1,284.7	19.7
Per cent utilized	....	....	72.6	95.6	97.2	77.3
Experiment No. 262, subject H. F. B.:						
Blancmange containing goose fat	2,424.0	1,100.3	44.6	312.9	947.8	18.4
Wheat biscuit	602.0	54.2	63.8	9.0	465.4	9.6
Fruit	1,178.0	1,023.7	9.4	2.4	136.6	5.9
Sugar	173.0	....	....	....	173.0	....
Total food consumed	4,377.0	2,178.2	117.8	324.3	1,722.8	33.9
Feces	153.0	....	39.7	21.5	80.4	11.4
Amount utilized	....	....	78.1	302.8	1,642.4	22.5
Per cent utilized	....	....	66.3	93.4	95.3	66.4
Experiment No. 264, subject R. L. S.:						
Blancmange containing goose fat	2,059.0	934.6	37.9	265.8	805.1	15.6
Wheat biscuit	321.0	28.9	34.0	4.8	248.1	5.2
Fruit	897.0	779.5	7.2	1.8	104.0	4.5
Sugar	72.0	....	....	....	72.0	....
Total food consumed	3,349.0	1,743.0	79.1	272.4	1,229.2	25.3
Feces	70.0	....	22.6	9.6	31.9	5.9
Amount utilized	....	....	56.5	262.8	1,197.3	19.4
Per cent utilized	....	....	71.4	96.5	97.4	76.7
Experiment No. 265, subject O. E. S.:						
Blancmange containing goose fat	2,451.0	1,112.5	45.1	316.4	958.4	18.6
Wheat biscuit	370.0	33.3	39.2	5.6	286.0	5.9
Fruit	1,219.0	1,059.3	9.8	2.4	141.4	6.1
Sugar	127.0	....	....	....	127.0	....
Total food consumed	4,167.0	2,205.1	94.1	324.4	1,512.8	30.6
Feces	108.0	....	30.9	17.5	51.8	7.8
Amount utilized	....	....	63.2	306.9	1,461.0	22.8
Per cent utilized	....	....	67.2	94.6	96.6	74.5
Experiment No. 282, subject H. F. B.:						
Blancmange containing goose fat	2,357.0	1,118.4	47.1	356.6	822.4	12.5
Wheat biscuit	501.0	45.1	53.1	7.5	387.3	8.0
Fruit	1,406.0	1,221.8	11.3	2.8	163.1	7.0
Sugar	165.0	....	....	....	165.0	....
Total food consumed	4,429.0	2,385.3	111.5	366.9	1,537.8	27.5
Feces	129.0	....	34.3	16.1	68.7	9.9
Amount utilized	....	....	77.2	350.8	1,469.1	17.6
Per cent utilized	....	....	69.2	95.6	95.5	64.0
Experiment No. 284, subject R. L. S.:						
Blancmange containing goose fat	1,469.0	697.0	29.4	222.3	512.5	7.8
Wheat biscuit	357.0	32.1	37.8	5.4	276.0	5.7
Fruit	452.0	392.8	3.6	0.9	52.4	2.3
Sugar	65.0	....	....	....	65.0	....
Total food consumed	2,343.0	1,121.9	70.8	228.6	905.9	15.8
Feces	83.0	....	26.8	17.7	29.7	8.8
Amount utilized	....	....	44.0	210.9	876.2	7.0
Per cent utilized	....	....	62.1	92.3	96.7	44.3

Data of digestion experiments with goose fat in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 285, subject O. E. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing goose fat	1,977.0	938.1	39.5	299.1	689.8	10.5
Wheat biscuit	405.0	36.4	42.9	6.1	313.1	6.5
Fruit	1,083.0	941.1	8.7	2.2	125.6	5.4
Sugar	174.0				174.0	
Total food consumed	3,639.0	1,915.6	91.1	307.4	1,302.5	22.4
Feces	99.0		26.5	25.9	38.9	7.7
Amount utilized			64.6	281.5	1,263.6	14.7
Per cent utilized			70.9	91.6	97.0	65.6
Average food consumed per subject per day	1,257.1	667.3	30.1	97.2	453.9	8.6

Summary of digestion experiments with goose fat in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
209	O. E. S.	72.6	95.6	97.2	77.3
262	H. F. B.	66.3	93.4	95.3	66.4
264	R. L. S.	71.4	96.5	97.4	76.7
265	O. E. S.	67.2	94.6	96.6	74.5
282	H. F. B.	69.2	95.6	95.5	64.0
284	R. L. S.	62.1	92.3	96.7	44.3
285	O. E. S.	70.9	91.6	97.0	65.6
	Average	68.5	94.2	96.5	67.0

The average coefficient of digestibility of the fat of the ration, of which over 97 per cent was goose fat, was 94.2 per cent, while 68.5 per cent of the protein and 96.5 per cent of the carbohydrate were retained in the body. Making allowance for the metabolic products and undigested fat (if any) from the basal ration occurring in the ether extract of the feces, the digestibility of goose fat becomes 95.2 per cent. In practically all the tests the subjects reported that the diet had a somewhat laxative effect; in fact, in two or three instances this was so pronounced that it was impossible to complete the test period and to secure the required experimental data. Since an average amount of 95 grams of goose fat was eaten daily, however, without any very pronounced physiological disturbances, it is reasonable to assume that goose fat in smaller amounts would not differ in such respects from other well-known fats, a conclusion borne out by the fact that users of the fat in other countries have found it not only wholesome but desirable.

BRISKET FAT.

In a previous paper [1] a study of the digestibility of beef kidney was reported in comparison with mutton kidney fat and pork kidney fat (lard), which showed differences in digestibility corresponding to the well-known chemical and physical differences between these fats.

[1] Loc. cit.

It seemed of interest also to study the digestibility of the fat from different parts of the same animal, since these are known to vary materially in composition, hardness, culinary qualities, etc. In a series of feeding experiments to determine the best ration to use for producing firm rather than soft pork, Shutt [1] found that the composition and physical properties of fat from animals receiving different rations varied considerably. In some cases the melting point of soft bacon was practically 10° C. lower than that of firm bacon, and the fat of very young pork was almost always softer than that of mature animals. Henriques and Hansen [2] investigated the properties of the outer layer of fat in an animal as compared with that in the interior of the same animal body, reporting that the inner and outer layers of fat are characterized by different iodin numbers and solidification points. In similar studies reported by Richardson,[3] the melting points of samples of leaf lard from oily hogs averaged several degrees higher than the back fat. Richardson and Farey [4] later found that the melting points of samples of back fat, leaf lard, and ham fat varied as much as 12° to 22° C.

While the fat of beef animals may not exhibit as wide a variation in physical characteristics as occurs in other animals, it is well known that brisket fat is quite different from kidney fat. It is softer and has a somewhat granular appearance and has some special culinary uses. Inasmuch as this variation in characteristics exists, it has seemed desirable to test whether there may be a corresponding difference in availability to the body. Accordingly, experiments were undertaken in which the digestibility of brisket fat was studied under conditions identical with those maintained in the study of beef kidney fat.

The material used for this purpose was purchased in the open market, separated from the connective tissues of the brisket by the method of rendering previously described, and incorporated in the blancmange which formed a part of the simple mixed diet used in the digestion experiments. The results of these experiments are tabulated on the following page.

[1] Canada Expt. Farms Rpts. 1899, pp. 151-155; Canada Expt. Farms Bul., 38 (1901).

[2] Skand. Arch. Physiol., 11 (1901), No. 3-4, pp. 151-165.

[3] Jour. Amer. Chem. Soc., 26 (1904), No. 4, pp. 372-374.

[4] Idem, 30 (1908), No. 7, pp. 1191, 1192.

Data of digestion experiments with brisket fat in a simple mixed diet.

	Weight.	Water.	Protien.	Fat.	Carbohydrates.	Ash.
Experiment No. 338, subject H. F. B.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing brisket fat	1,915.0	817.3	40.7	299.1	750.0	7.9
Wheat biscuit	404.0	37.9	40.4	5.9	313.4	6.4
Fruit	1,705.0	1,481.7	13.6	3.4	197.8	8.5
Sugar	205.0				205.0	
Total food consumed	4,229.0	2,336.9	94.7	308.4	1,466.2	22.8
Feces	117.0		42.0	18.2	44.8	12.0
Amount utilized			52.7	290.2	1,421.4	10.8
Per cent utilized			55.6	94.1	96.9	47.4
Experiment No. 339, subject D. G. G.:						
Blancmange containing brisket fat	1,611.0	687.6	34.2	251.6	631.0	6.6
Wheat biscuit	492.0	46.1	49.2	7.2	381.7	7.8
Fruit	1,326.0	1,152.3	10.6	2.7	153.8	6.6
Sugar	113.0				113.0	
Total food consumed	3,542.0	1,886.0	94.0	261.5	1,279.5	21.0
Feces	97.0		33.3	14.9	40.5	8.3
Amount utilized			60.7	246.6	1,239.0	12.7
Per cent utilized			64.6	94.3	96.8	60.5
Experiment No. 340, subject R. L. S.:						
Blancmange containing brisket fat	1,845.0	787.4	39.2	288.2	722.6	7.6
Wheat biscuit	336.0	31.5	33.6	4.9	260.7	5.3
Fruit	1,318.0	1,145.3	10.6	2.6	152.9	6.6
Sugar	117.0				117.0	
Total food consumed	3,616.0	1,964.2	83.4	295.7	1,253.2	19.5
Feces	92.0		27.1	12.2	43.6	9.1
Amount utilized			56.3	283.5	1,209.6	10.4
Per cent utilized			67.5	95.9	96.5	53.3
Experiment No. 341, subject O. E. S.:						
Blancmange containing brisket fat	1,887.0	805.4	40.1	294.8	739.0	7.7
Wheat biscuit	364.0	34.1	36.4	5.3	282.4	5.8
Fruit	1,627.0	1,413.9	13.0	3.3	188.7	8.1
Sugar	338.0				338.0	
Total food consumed	4,216.0	2,253.4	89.5	303.4	1,548.1	21.6
Feces	109.0		36.8	17.3	44.3	10.6
Amount utilized			52.7	286.1	1,503.8	11.0
Per cent utilized			58.9	94.3	97.1	50.9
Experiment No. 347, subject D. G. G.:						
Blancmange containing brisket fat	1,342.0	741.3	26.9	150.3	418.0	5.5
Wheat biscuit	388.0	34.9	41.1	5.8	300.0	6.2
Fruit	1,547.0	1,344.3	12.4	3.1	179.5	7.7
Sugar	92.0				92.0	
Total food consumed	3,369.0	2,120.5	80.4	159.2	989.5	19.4
Feces	121.0		41.0	17.4	52.0	10.6
Amount utilized			39.4	141.8	937.5	8.8
Per cent utilized			49.0	89.1	94.7	45.4
Experiment No. 348, subject R. L. S.:						
Blancmange containing brisket fat	1,509.0	833.6	30.2	169.0	470.0	6.2
Wheat biscuit	311.0	28.0	33.0	4.6	240.4	5.0
Fruit	1,440.0	1,251.4	11.5	2.9	167.0	7.2
Sugar	45.0				45.0	
Total food consumed	3,305.0	2,113.0	74.7	176.5	922.4	18.4
Feces	83.0		28.8	17.9	28.4	7.9
Amount utilized			45.9	158.6	894.0	10.5
Per cent utilized			61.4	89.9	96.9	57.1
Experiment No. 349, subject O. E. S.:						
Blancmange containing brisket fat	1,936.0	1,069.5	38.7	216.8	603.1	7.9
Wheat biscuit	289.0	26.0	30.6	4.4	223.4	4.6
Fruit	2,314.0	2,010.9	18.5	4.6	268.4	11.6
Sugar	259.0				259.0	
Total food consumed	4,798.0	3,106.4	87.8	225.8	1,353.9	24.1
Feces	128.0		42.6	17.6	56.2	11.6
Amount utilized			45.2	208.2	1,297.7	12.5
Per cent utilized			51.5	92.2	95.8	51.9
Average food consumed per subject per day	1,289.3	751.4	28.8	82.4	419.7	7.0

Summary of digestion experiments with brisket fat in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
338	H. F. B	55.6	94.1	96.9	47.4
339	D. G. G	64.6	94.3	96.8	60.5
340	R. L. S	67.5	95.9	96.5	53.3
341	O. E. S	58.9	94.3	97.1	50.9
347	D. G. G	49.0	89.1	94.7	45.4
348	R. L. S	61.4	89.9	96.9	57.1
349	O. E. S	51.5	92.2	95.8	51.9
	Average	58.4	92.8	96.4	52.4

The data of the experiments indicate that the ration supplied 82 grams of fat daily and that this was 92.8 per cent digested. When allowance is made for the small quantity of fat in the basal ration and for the metabolic products in the corresponding feces, the digestibility of brisket fat alone becomes 97.4 per cent. The protein and carbohydrate contained in the diet were 58.4 per cent and 96.4 per cent digested, respectively.

It is interesting to note that the brisket fat is somewhat more completely assimilated than the kidney fat, of which 93 per cent was digested,[1] on an average. Although this difference is not very great, it may contribute added evidence to the theory that the properties of fats vary with the part of the animal body from which the fats are taken.

CREAM.

Owing to the pleasant taste and its very general use in the dietary, the digestibility of milk fat in the form of cream rather than as a separated fat like butter is of particular interest. The question as to whether an emulsion or the separated fat is the more thoroughly digested has been studied by Wells,[2] who found in the case of cod-liver oil that very little difference existed in the digestibility of the two forms. In a series of experiments to determine the influence on metabolism of an excess of fat in the diet, Atwater [3] found that an average of 320 grams of fat daily in a simple mixed diet was 98 per cent digested. Approximately 85 per cent of the total quantity of fat eaten was furnished by cream and milk.

The digestibility of butter, as determined in this office in a series of eight experiments, was found to be 97 per cent,[4] and in a later series of tests, in which the digestibility of the protein of hard palates was studied, butter was found to be 95 per cent digested.[5] Due very possibly to the belief that milk fat in all its forms is equally available to the body, very few similar studies of cream have been reported.

[1] U. S. Dept. Agr. Bul. 310 (1915).

[2] Brit. Med. Jour., 2 (1902), No. 2181, pp. 1222-1224.

[3] Connecticut Storrs Sta. Rpt. 1901, pp. 230-233.

[4] U. S. Dept. Agr. Bul. 310 (1915), p. 21.

[5] U. S. Dept. Agr., Jour. Agr. Research, 6 (1916), No. 17, pp. 641-648.

A series of experiments, accordingly, has been made to determine the digestibility of cream in comparison with that of other fats.

Cream of average quality was purchased of a local dealer and incorporated in a blancmange in the manner previously described, except that, owing to the larger volume of the cream, no skim milk was necessary and a much smaller amount of cornstarch was needed to thicken the mixture. The results of seven digestion experiments, in which five different subjects participated, follow:

Data of digestion experiments with cream in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 180, subject R. L. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing cream	1,461.0	738.8	30.5	149.2	534.3	8.2
Wheat biscuit	328.0	29.5	34.8	4.9	253.5	5.3
Fruit	1,116.0	969.8	8.9	2.2	129.5	5.6
Sugar	82.0				82.0	
Total food consumed	2,987.0	1,738.1	74.2	156.3	999.3	19.1
Feces	69.0		21.7	10.6	29.6	7.1
Amount utilized			52.5	145.7	969.7	12.0
Per cent utilized			70.8	93.2	97.0	62.8
Experiment No. 181, subject O. E. S.:						
Blancmange containing cream	1,803.0	911.8	37.7	184.1	659.3	10.1
Wheat biscuit	145.0	13.0	15.4	2.2	112.1	2.3
Fruit	1,547.0	1,344.3	12.4	3.1	179.5	7.7
Sugar	197.0				197.0	
Total food consumed	3,692.0	2,269.1	65.5	189.4	1,147.9	20.1
Feces	69.0		18.8	11.4	33.4	5.4
Amount utilized			46.7	178.0	1,114.5	14.7
Per cent utilized			71.3	94.0	97.1	73.1
Experiment No. 182, subject R. F. T.:						
Blancmange containing cream	1,885.0	953.2	39.4	192.5	689.3	10.6
Wheat biscuit	11.0	1.0	1.2	0.1	8.5	0.2
Fruit	1,580.0	1,373.0	12.6	3.2	183.3	7.9
Sugar	88.0				88.0	
Total food consumed	3,564.0	2,327.2	53.2	195.8	969.1	18.7
Feces	60.0		12.9	14.2	26.5	6.4
Amount utilized			40.3	181.6	942.6	12.3
Per cent utilized			75.8	92.7	97.3	65.8
Experiment No. 306, subject H. F. B.:						
Blancmange containing cream	2,102.0	1,101.7	47.3	281.2	661.3	10.5
Wheat biscuit	523.0	47.1	55.4	7.8	404.3	8.4
Fruit	717.0	623.1	5.7	1.4	83.2	3.6
Sugar	157.0				157.0	
Total food consumed	3,499.0	1,771.9	108.4	290.4	1,305.8	22.5
Feces	140.0		40.2	23.2	64.8	11.8
Amount utilized			68.2	267.2	1,241.0	10.7
Per cent utilized			62.9	92.0	95.0	47.6
Experiment No 307, subject D. G G.:						
Blancmange containing cream	2,179.0	1,142.0	49.0	291.6	685.5	10.9
Wheat biscuit	485.0	43.6	51.4	7.3	374.9	7.8
Fruit	369.0	320.7	3.0	0.7	42.8	1.8
Sugar	137.0				137.0	
Total food consumed	3,170.0	1,506.3	103.4	299.6	1,240.2	20.5
Feces	184.0		59.3	32.1	76.2	16.4
Amount utilized			44.1	267.5	1,164.0	4.1
Per cent utilized			43.0	89.3	93.9	12.3

Data of digestion experiments with cream in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Experiment No. 308, subject R. L. S.:						
Blancmange containing cream	2,063.0	1,081.2	46.4	276.1	649.0	10.3
Wheat biscuit	330.0	29.7	35.0	4.9	255.1	5.3
Fruit	313.0	272.0	2.5	0.6	36.3	1.6
Sugar	64.0				64.0	
Total food consumed	2,770.0	1,382.9	83.9	281.6	1,004.4	17.2
Feces	87.0		28.7	20.4	28.5	9.4
Amount utilized			55.2	261.2	975.9	7.8
Per cent utilized			65.8	92.8	97.2	45.3
Experiment No. 309, subject O. E. S.:						
Blancmange containing cream	2,017.0	1,057.1	45.4	269.9	634.5	10.1
Wheat biscuit	398.0	35.8	42.2	6.0	307.6	6.4
Fruit	767.0	666.5	6.1	1.5	89.0	3.9
Sugar	191.0				191.0	
Total food consumed	3,373.0	1,759.4	93.7	277.4	1,222.1	20.4
Feces	109.0		31.3	13.4	55.4	8.9
Amount utilized			62.4	264.0	1,166.7	11.5
Per cent utilized			66.6	95.2	95.5	56.4
Average food consumed per subject per day	1,097.9	607.4	27.7	80.5	375.7	6.6

Summary of digestion experiments with cream in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
180	R. L. S.	70.8	93.2	97.0	62.8
181	O. E. S.	71.3	94.0	97.1	73.1
182	R. F. T.	75.8	92.7	97.3	65.8
306	H. F. B.	62.9	92.0	95.0	47.6
307	D. G. G.	43.0	89.3	93.9	12.3
308	R. L. S.	65.8	92.8	97.2	45.3
309	O. E. S.	66.6	95.2	95.5	56.4
	Average	65.2	92.7	96.1	51.9

It is shown in the summary of the data reported above that the average values for the digestibility of protein, fat, and carbohydrate were 65.2, 92.7, and 96.1 per cent, respectively, when 28, 81, and 376 grams of these constituents were eaten per subject daily. The apparent digestibility of 92.7 per cent for fat becomes 96.9 per cent if allowance is made for the metabolic products and fat of the basal ration occurring in the feces. It was anticipated that much more than 78 grams of milk fat or "butter" would be eaten per subject per day, but the subjects reported that, although the blancmange was of better flavor and smoother texture than that to which they were accustomed, they did not eat as much as usual owing to its being "too rich." The results of the experiments in general, however, would indicate that butter fat supplied in the form of cream is very well assimilated by the body.

EGG-YOLK FAT.

While egg-yolk fat is not separated from eggs for use as food, it has an important place in the dietary, as is evident from the estimate that each egg supplies about 10 grams of the fat. From the results of a large number of dietary studies, Atwater [1] found that over 4 per cent of the total fat of the diet was furnished by egg yolks. The digestibility of this fat is interesting on these grounds alone, but when it is considered that egg-yolk fat has associated with it other very necessary constituents of the diet, namely, the so-called "growth-maintaining or stimulating factors," which have been the object of considerable recent investigation, it becomes of especial interest. Osborne and Mendel [2] and McCollum and Davis [3] have studied the maintenance and growth-stimulating properties of many fats and have found that egg-yolk fat is one of very few which are efficient in this respect, and it is also a fat relatively rich in lecithin.

Although there is little experimental evidence on the subject, it is generally said that egg yolks are very quickly and completely digested. Observations and experiments on the treatment of the underfed led Stern [4] to conclude that egg yolks are well tolerated and that they may be used to supply a large proportion of the fat of the diet. He found that eggs left the human stomach in from one to one and a half hours, and that the coefficient of digestibility of the fat (as shown by comparison of the food and feces) was from 96.5 to 98.5 per cent.

These results are substantiated by the work of Levites [5] on dogs, in which he found that egg-yolk fat was digested in from one to four hours. This author concluded that egg-yolk fat behaved differently from other fats in the process of digestion, in that the contents removed from the stomach of dogs which had been given egg-yolk fat showed an alkaline reaction, whereas with olive oil an acid reaction was obtained.

According to Lewkowitsch,[6] egg-yolk fat as expressed from the yolks of hard-boiled hen eggs is a yellow oil, while that obtained by ether extraction is a semisolid oil of an orange-yellow color. For the purpose of these experiments, however, it was not considered necessary to express or extract the oil, but instead it was fed as it occurs in the egg. The yolks were carefully separated from the whites, beaten, and incorporated directly in the blancmange, less cornstarch being required, owing to the well-known thickening properties of egg yolks. The blancmange made with egg yolk had a different consistency from that used in previous experiments, being more adhesive and pastelike. It also had a characteristic "eggy" flavor and furnished about four times as much nitrogen as the blancmange made with other fats. Five young men, living under normal conditions, assisted in the experiments reported on the following page.

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[1] Connecticut Storrs Sta. Rpt. 1899, p. 82.
[2] Jour. Biol. Chem., 17 (1914), No. 3, p. 405.
[3] Idem, 15 (1913), No. 1, pp. 167–175.
[4] Med. Rec. [N. Y.], 66 (1904), No. 27, pp. 1049–1052.
[5] Biochem. Ztschr., 20 (1909), No. 3-5, pp. 220–223.
[6] Chemical Technology and Analysis of Oils, Fats, and Waxes. London: Macmillan & Co., 1909, 4. ed., vol. 2, p. 395.

Data of digestion experiments with egg yolk in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 214, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing egg-yolk fat	1,826.0	769.7	151.7	267.0	619.3	18.3
Wheat biscuit	303.0	27.3	32.1	4.5	234.2	4.9
Fruit	599.0	520.5	4.8	1.2	69.5	3.0
Sugar	172.0	....	....	....	172.0	....
Total food consumed	2,900.0	1,317.5	188.6	272.7	1,095.0	26.2
Feces	107.0	....	31.8	21.8	44.1	9.3
Amount utilized	....	....	156.8	250.9	1,050.9	16.9
Per cent utilized	....	....	83.1	92.0	96.0	64.5
Experiment No. 215, subject R. L. S.:						
Blancmange containing egg-yolk fat	1,669.0	703.5	138.7	244.0	566.1	16.7
Wheat biscuit	294.0	26.4	31.2	4.4	227.3	4.7
Fruit	648.0	563.1	5.2	1.3	75.2	3.2
Sugar	116.0	....	....	....	116.0	....
Total food consumed	2,727.0	1,293.0	175.1	249.7	984.6	24.6
Feces	103.0	....	32.7	21.5	38.4	10.4
Amount utilized	....	....	142.4	228.2	946.2	14.2
Per cent utilized	....	....	81.3	91.4	96.1	57.7
Experiment No. 216, subject O. E. S.:						
Blancmange containing egg-yolk fat	1,921.0	809.7	159.6	280.9	651.6	19.2
Wheat biscuit	197.0	17.7	20.9	3.0	152.3	3.1
Fruit	1,786.0	1,552.0	14.3	3.6	207.2	8.9
Sugar	224.0	....	....	....	224.0	....
Total food consumed	4,128.0	2,379.4	194.8	287.5	1,235.1	31.2
Feces	104.0	....	30.9	23.8	38.5	10.8
Amount utilized	....	....	163.9	263.7	1,196.6	20.4
Per cent utilized	....	....	84.1	91.7	96.9	65.4
Experiment No. 217, subject R. F. T.:						
Blancmange containing egg-yolk fat	1,220.0	514.2	101.4	178.4	413.8	12.2
Wheat biscuit	51.0	4.6	5.4	.8	39.4	0.8
Fruit	1,731.0	1,504.2	13.8	3.5	200.8	8.7
Sugar	162.0	....	....	....	162.0	....
Total food consumed	3,164 0	2,023.0	120.6	182.7	816.0	21.7
Feces	62.0	....	17.4	16.4	20.0	8.2
Amount utilized	....	....	103.2	166.3	796.0	13.5
Per cent utilized	....	....	85.6	91.0	97.5	62.2
Experiment No. 302, subject H. F. B.:						
Blancmange containing egg-yolk fat	1,316.0	507.2	111.9	251.6	436.9	8.4
Wheat biscuit	456.0	41.0	48.3	6.9	352.5	7.3
Fruit	736.0	639.6	5.9	1.5	85.3	3.7
Sugar	43.0	....	....	....	43.0	....
Total food consumed	2,551.0	1,187.8	166.1	260.0	917.7	19.4
Feces	127.0	....	41.3	23.7	50.8	11.2
Amount utilized	....	....	124.8	236.3	866.9	8.2
Per cent utilized	....	....	75.1	90.9	94.5	42.3
Experiment No. 303, subject O. E. S.:						
Blancmange containing egg-yolk fat	1,380.0	531.9	117.3	263.8	458.2	8.8
Wheat biscuit	330.0	29.7	35.0	4.9	255.1	5.3
Fruit	971.0	843.8	7.8	1.9	112.6	4.9
Sugar	....	....	....	....	....	....
Total food consumed	2,681.0	1,405.4	160.1	270.6	825.9	19.0
Feces	96.0	....	31.8	21.5	33.9	8.8
Amount utilized	....	....	128.3	249.1	792.0	10.2
Per cent utilized	....	....	80.1	92.1	95.9	53.7
Average food consumed per subject per day	1,008.4	533.7	55.9	84.6	326.3	7.9

Summary of digestion experiments with egg yolk in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
214	D. G. G.	83.1	92.0	96.0	64.5
215	R. L. S.	81.3	91.4	96.1	57.7
216	O. E. S.	84.1	91.7	96.9	65.4
217	R. F. T.	85.6	91.0	97.5	62.2
302	H. F. B.	75.1	90.9	94.5	42.3
303	O. E. S.	80.1	92.1	95.9	53.7
	Average	81.6	91.5	96.2	57.6

It may be noted from the recorded data of these experiments that the average amounts of protein, fat, and carbohydrate eaten daily were 56, 85, and 326 grams, of which 81.6, 91.5, and 96.2 per cent were digested, respectively. The reported digestibility of 91.5 per cent for the total fat of the diet is increased to 93.8 per cent for the egg-yolk fat by making allowance for metabolic products and any undigested portion of the small amount of fat the basal ration supplied. Inasmuch as the egg-yolk fat comprised 98 per cent of all the fat supplied by the diet, this derived value should very closely approximate the true digestibility of egg-yolk fat.

In the course of the analytical work it was observed that the ether extracts of both the blancmange and the feces of the experimental periods were of a very dark-orange color, somewhat more intense in the case of the feces. This discoloration can probably be attributed to coloring matter extracted from the egg yolk.

FISH FAT.

Though fish fat or oil (for it is liquid at ordinary room temperature) is not a culinary or table fat in our temperate regions, nevertheless, as it occurs in fish flesh, it forms a not inconsiderable part of the total fat of the diet. This is particularly the case in localities where such fish as mackerel, butterfish, salmon, shad, etc., are eaten in quantity. Except in the case of cod-liver oil, which is a special product used in invalid dietetics chiefly because of the medicinal properties attributed to it, experimental studies of food uses of fish fat or oil are apparently few in number.

Atwater,[1] in a study of haddock compared with beef, reports that the fish fat was 91 per cent digested. Some years later Milner,[2] in experiments with four young men, found that the digestibility of the fat of a lean fish (cod) was practically the same as that of a fat fish (canned salmon), the values being 97.4 per cent and 97 per cent, respectively.

Since fish oil suitable for food purposes was not found on the market and it was not practicable to prepare it in the laboratory, fish containing a fairly high percentage of fat was used instead in the experi-

[1] Ztschr. Biol., 24 (1888), pp. 16–28.

[2] Connecticut Storrs Sta. Rpt. 1905, pp. 116–142.

ments here reported. For convenience it was served in the form of a fish loaf rather than incorporated in a cornstarch blancmange, such as was used with the other fats. With the fish loaf a simple basal ration was served which consisted of potato (boiled and mashed) and biscuits or crackers, fruit (raw apples), and sugar with tea or coffee when such beverages were preferred to water. A small amount of lemon juice was used with the fish as a condiment, but no account was taken of it in computing the nutritive value of the ration.

The fish loaf was prepared as follows: Boston mackerel (a typical fat fish), weighing when cleaned approximately 3 pounds each, were washed and cooked in a covered pan for half an hour in a moderate oven, a little water being added so that the fish would not stick to the pan. The bones, skin, etc., were then removed and the fish flesh minced in an ordinary household meat cutter. The small amount of liquid which remained in the pan was mixed with the minced fish to avoid the loss of any fat which had "cooked out." After seasoning moderately with salt and pepper, the minced fish was formed into a loaf and baked two or three hours in a moderate oven. The crusty surface was removed and the inside portion of the loaf was thoroughly mixed and divided into suitable quantities for the subjects' meals.

Though different in form, the diet was similar in nutritive value to those in the other experiments here reported, fish protein replacing the protein of the skim milk used in making the cornstarch blancmange and mashed potato replacing the cornstarch. That the diets were directly comparable in nutritive value is evident from a comparison of the protein, fat, and energy which the subjects obtained per day from each.

The details of the three experiments which were made follow.

Data of digestion experiments with Boston mackerel in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 444, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Boston mackerel (in form of fish loaf)	1,496.0	926.0	323.0	199.9	....	47.1
Potato	439.0	331.5	11.0	.4	91.7	4.4
Crackers	284.0	19.6	23.0	38.0	201.1	2.3
Fruit	1,320.0	1,116.7	5.3	6.6	187.4	4.0
Sugar	171.0	....	....	....	171.0	....
Total food consumed	3,710.0	2,393.8	362.3	244.9	651.2	57.8
Feces	67.0	....	19.3	10.1	31.9	5.7
Amount utilized	....	....	343.0	234.8	619.3	52.1
Per cent utilized	....	....	94.7	95.9	95.1	90.1
Experiment No. 446, subject R. L. S.:						
Boston mackerel (in form of fish loaf)	1,184.0	732.9	255.6	158.2	....	37.3
Potato	227.0	171.4	5.7	.2	47.4	2.3
Crackers	243.0	16.8	19.7	32.6	172.0	1.9
Fruit	1,376.0	1,164.1	5.5	6.9	195.4	4.1
Sugar	58.0	....	....	....	58.0	....
Total food consumed	3,088.0	2,085.2	286.5	197.9	472.8	45.6
Feces	53.0	....	21.9	7.5	16.2	7.4
Amount utilized	....	....	264.6	190.4	456.6	38.2
Per cent utilized	....	....	92.4	96.2	96.6	83.8

Data of digestion experiments with Boston mackerel in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 447, subject O. E. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Boston mackerel (in form of fish loaf)	1,348.0	834.4	291.0	180.1	....	42.5
Potato	476.0	359.4	11.9	.5	99.5	4.7
Crackers	171.0	11.8	13.8	22.9	121.1	1.4
Fruit	1,594.0	1,348.5	6.4	8.0	226.3	4.8
Sugar	165.0	....	....	....	165.0	....
Total food consumed	3,754.0	2,554.1	323.1	211.5	611.9	53.4
Feces	70.0	....	28.6	12.2	21.6	7.6
Amount utilized	....	....	294.5	199.3	590.3	45.8
Per cent utilized	....	....	91.1	94.2	96.5	85.8
Average food consumed per subject per day	1,172.5	781.5	108.0	72.7	192.9	17.4

Summary of digestion experiments—Digestibility of nutrients of entire diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
444	D. G. G	94.7	95.9	95.1	90.1
446	R. L. S	92.4	96.2	96.6	83.8
447	O. E. S	91.1	94.2	96.5	85.8
	Average	92.7	95.4	96.1	86.6

As the tables show, the experimental diet supplied, on an average, 108 grams protein, 73 grams fat, and 193 grams carbohydrates per day. The coefficients of digestibility of the entire diet were: Protein, 92.7 per cent; fat, 95.4 per cent; and carbohydrates, 96.1 per cent.

The amount of fat supplied by other foods than fish was only 17.7 per cent of the total fat of the diet. Making due allowance for this small amount of fat other than fish fat made no significant change, the corrected value being 95.2 per cent as compared with 95.4 per cent. This is comparable with the values obtained for other fats of similar physical characteristics and indicates that, like them, fish fat is well assimilated.

SUMMARY.

The fats studied in this investigation were well digested, the coefficients of digestibility, with allowance for metabolic products and any undigested fat supplied by the basal ration, being, for chicken fat, 96.7 per cent; for goose fat, 95.2 per cent; for brisket fat, 97.4 per cent; for butter fat in the form of cream, 96.9 per cent; for the fat in egg yolk, 93.8 per cent; and for the fat in fish flesh, 95.2 per cent.

On an average, 95 grams of chicken fat, 95 grams of goose fat, 80 grams of brisket fat, 78 grams of butter fat in the form of cream, 83 grams of egg-yolk fat, and 60 grams of fish fat were eaten per subject per day. In the case of goose fat, the feces were noticeably soft and occasionally a more decided laxative effect was noted, indicating that the limit of tolerance for this fat was not far above the 95 grams

which was eaten on an average. No physiological disturbance was noted with the other fats tested. Such matters have a practical value in discussing dietetics, aside from the theoretical question whether this laxative property is ascribable to differences in the chemical structure of the fats or to some other factor.

The average coefficient of digestibility of brisket fat is higher than that previously found for beef (kidney) fat (93 per cent),[1] which is in accordance with the observation that the digestibility is inversely proportional to the melting point. The other fats studied were either fluid or had a melting point not far from room temperature, so it was not surprising to find that they did not show marked variations in thoroughness of digestion.

The average digestibility of carbohydrates in the different tests was found to vary only from 96.1 to 96.9 per cent, while the digestibility of this food constituent in the average mixed diet has been found to be 97 per cent.[2] This close agreement would indicate that the consumption of fat did not exercise any unusual effect upon carbohydrate digestion.

As a whole, the results of the digestion experiments indicate that chicken fat, goose fat, brisket fat, cream, egg-yolk fat, and fish fat are all well assimilated and that they are satisfactory sources of fat for the dietary. Since butter fat eaten in the form of cream and egg-yolk fat are very thoroughly digested and easily obtainable and apparently contain or carry with them accessory food substances necessary in the diet for growth and general well-being, a wide use of these two fats in the dietary is especially desirable.

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[1] U. S. Dept. Agr. Bul. 310, p. 21.
[2] Connecticut Storrs Sta. Rpt. 1901, p. 245.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATIVE TO FOOD AND NUTRITION.

AVAILABLE FOR FREE DISTRIBUTION.

Meats: Composition and Cooking. By Chas. D. Woods. Pp. 31, figs. 4. 1904. (Farmers' Bulletin 34.)

The Use of Milk as Food. By R. D. Milner. Pp. 44. 1911. (Farmers' Bulletin 363.)

Care of Food in the Home. By Mrs. Mary Hinman Abel. Pp. 46, figs. 2. 1910. (Farmers' Bulletin 375.)

Economical Use of Meat in the Home. By C. F. Langworthy and Caroline L. Hunt. Pp. 30. 1910. (Farmers' Bulletin 391.)

Cheese and Its Economical Uses in the Diet. By C. F. Langworthy and Caroline L. Hunt. Pp. 40. 1912. (Farmers' Bulletin 487.)

Mutton and Its Value in the Diet. By C. F. Langworthy and Caroline L. Hunt. Pp. 32, figs. 2. 1913. (Farmers' Bulletin 526.)

The Detection of Phytosterol in Mixtures of Animal and Vegetable Fats. By R. H. Kerr. Pp. 4. 1913. (Bureau of Animal Industry Circular 212.)

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

Experiments on Losses in Cooking Meat, 1900–1903. By H. S. Grindley, D. Sc., and Timothy Mojonnier, M. S. Pp. 95, tables 82. 1904. (Office of Experiment Stations Bulletin 141.) Price. 5 cents.

Studies on the Influence of Cooking upon the Nutritive Value of Meats at the University of Illinois, 1903–1904. By H. S. Grindley, Sc. D., and A. D. Emmett, A. M. Pp. 230, tables 136. 1905. (Office of Experiment Stations Bulletin 162.) Price, 20 cents.

Studies of the Effect of Different Methods of Cooking upon the Thoroughness and Ease of Digestion of Meats at the University of Illinois. H. S. Grindley, D. Sc., Timothy Mojonnier, M. S., and Horace C. Porter, Ph. D. Pp. 100, tables 38. 1907. (Office of Experiment Stations Bulletin 193.) Price. 15 cents.

Food Customs and Diet in American Homes. By C. F. Langworthy, Ph. D. Pp. 32. 1911. (Office of Experiment Stations Circular 110.) Price, 5 cents.

Digestibility of Some Animal Fats. By C. F. Langworthy and A. D. Holmes. Pp. 23. 1915. (Department Bulletin 310.) Price, 5 cents.

Digestibility of Very Young Veal. By C. F. Langworthy and A. D. Holmes. Pp. 577–588. 1916. (Journal of Agricultural Research, 6 (1916), No. 16.) Price. 5 cents.

Digestibility of Hard Palates of Cattle. By C. F. Langworthy and A. D. Holmes. Pp. 641–648. 1916. (Journal of Agricultural Research, 6 (1916), No. 17.) Price, 5 cents.

Studies on the Digestibility of the Grain Sorghums. By C. F. Langworthy and A. D. Holmes. Pp. 30. 1916. (Department Bulletin 470.) Price, 5 cents.

Fats and their Economical Use in the Home. By A. D. Holmes and H. L. Lang. Pp. 26. 1916. (Department Bulletin 469.) Price 5, cents.

Digestibility of Some Vegetable Fats. By C. F. Langworthy and A. D. Holmes. Pp. 20. 1917. (Department Bulletin 505.) Price, 5 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 508

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER March 6, 1917

YIELDS FROM THE DESTRUCTIVE DISTILLATION OF CERTAIN HARDWOODS.

SECOND PROGRESS REPORT.

By R. C. PALMER, *Chemist in Forest Products.*

CONTENTS.

PURPOSE OF EXPERIMENTS.

The object of the investigations reported in this bulletin and in Bulletin 129, to which this is supplementary, was to determine the relative value of the various hardwoods commonly used for destructive distillation, and of the different forms of material, such as bodywood, limbs, and slabs. The experiments were carried on at the Forest Products Laboratory, maintained at Madison, Wis., in cooperation with the University of Wisconsin. The standard species—beech, birch, and hard maple—were included in the laboratory tests so as to make the results on other species comparable with them and hence commercially applicable. Bulletin 129 gives the yields for these three standard species, and, in addition, red gum, chestnut, hickory, white oak, and tupelo. The present bulletin gives the yields for white elm, slippery elm, silver maple, green ash, blue ash, yellow ash, chestnut oak, tanbark oak, California black oak, Louisiana swamp oak,[1] and eucalyptus.

The results here reported are of most value when compared with laboratory distillations of species whose yields in commercial prac-

[1] "Swamp oak" was a mixture of laurel, post, water, willow, Spanish, and cow oaks, usually growing in mixed stands. Acknowledgment is made of the assistance of Mr. H. Cloukey in analyzing some of the distillates.

NOTE.—This bulletin gives the results of experiments in destructive distillation of hardwoods and is of interest to manufacturers of by-products.

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tice are well known. Laboratory methods of distilling are not comparable directly with commercial conditions, and the calculated yields per cord from laboratory distillations on 100 or 200 pounds of material are frequently much higher than the yields from distilling several thousand pounds in the commercial plant.

PLAN OF INVESTIGATION.

The apparatus used and the manner of making the tests are described in Bulletin 129. Both body and slab wood were distilled in most cases and in a few species limb wood was included in the study.

The yields of wood alcohol and acetic acid were determined by analysis of the pyroligneous-acid liquor,[1] and the amount of tar and charcoal was determined by measurement. The average was taken of three or four tests on each form of material.

METHOD OF RECORDING DATA.

The yields are expressed in three ways: (1) As a proportion of the oven-dry weight of the wood distilled (it is only on this basis that the results are independent of varying percentages of moisture in the material and of differences in the weight of unit volumes); (2) in the commercial units, gallons of 82 per cent crude wood alcohol and pounds of 80 per cent gray acetate of lime per cord of air-dry wood;[2] and (3) as a proportion of the yield of a cord of equal parts of beech, birch, and maple.

YIELDS ON PERCENTAGE WEIGHT BASIS, ALCOHOL AND ACETIC ACID.

VARIATION AMONG SPECIES.

The average yields of acetic acid and wood alcohol expressed in percentages based on the oven-dry weight of the material distilled are given in Table 1. The yields from a previous study of the standard species, beech, birch, and maple, are given for comparison. On this basis several of the species tested compare very favorably with the standard species. White elm, slippery elm, silver maple, and black ash gave nearly the same yields of alcohol as beech and hard maple. The acetic-acid yield of white elm, silver maple (heartwood), tanbark oak, and California black oak (limbs) were very nearly the same as that of birch, and considerably larger than the yield of beech and maple.

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[1] The methods of analysis are given in Klar's Technologie der Holzverkohlung, p. 337, except that in the alcohol analysis a final distillation is made after adding a few cubic centimeters of concentrated H_2SO_4 to eliminate the wood-oil constituents.

[2] A cord of air-dry wood is assumed for purposes of comparison to be equal to 90 cubic feet of solid wood containing 15 per cent moisture (calculated on the dry weight). The weights per cubic foot of wood are those given in "The Principal Species of Wood," by C. H. Snow. Recent investigations by the Forest Service show weights per cubic foot slightly different from those used in these calculations, but the relative values are not changed.

TABLE 1.—*Yields of alcohol and acetic acid in percentages based on the oven-dry weight of the material distilled.*

Species.	Locality.	Wood alcohol (100 per cent).			Total acetic acid.		
		Heartwood.	Slabwood.	Mean heartwood and slabwood.	Heartwood.	Slabwood.	Mean heartwood and slabwood.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Beech	Indiana	1.95	1.79	1.87	5.56	6.18	5.87
Birch	Wisconsin	1.45	1.55	1.50	6.71	6.88	6.80
Maple	do	1.94	1.91	1.93	5.42	5.11	5.26
White elm	Pennsylvania	2.12	1.68	1.90	6.39	[1] 6.61	6.50
Slippery elm	Wisconsin	2.03	1.79	1.91	5.77	5.53	5.65
Silver maple	do	1.89	1.77	1.83	6.30	5.31	5.81
Green, blue, and yellow ash.	Tennessee and Missouri.	1.91	1.43	1.67	4.64	4.14	4.39
Black ash	Wisconsin	1.79	2.04	1.91	5.65	5.16	5.40
Green ash	Missouri	....	....	[2] 2.02	....	....	[2] 4.51
Chestnut oak [3]	Tennessee	1.22	1.30	1.27	4.88	4.91	4.90
Tanbark oak	California	1.72	....	....	6.89	....	....
Black oak	do	....	1.53	[2] 1.66	....	6.01	[2] 6.76
Swamp oak	Louisiana	1.50	1.31	1.40	4.90	5.43	5.16
Eucalyptus	California	1.33	1.68	1.50	4.58	5.31	4.94

[1] One-third of this sample was slab free from bark.
[2] Limbs.
[3] In case of chestnut oak the mean is not the average, since the slab represented more runs than heart.

VARIATION DUE TO FORM OF MATERIAL.

The elms, silver maple, green ash, blue ash, yellow ash, and swamp oak gave larger yields of alcohol from heartwood than from slabs, but black ash, chestnut oak, and eucalyptus gave the larger returns from the slabwood. Chestnut oak, white elm, and eucalyptus slabwood yielded more acetic acid than the heartwood of these species, following the tendency previously noted in several other species for sapwood to give more acid than heartwood. California black oak limbs (practically all sapwood) gave a large yield of acid.[1] Silver maple yielded more acid from heartwood than from sapwood.

YIELDS PER CORD, ALCOHOL AND ACETATE.

COMPARISON OF YIELDS.

Table 2 is a conversion to a commercial basis of the results given in Table 1. The raw material is expressed in terms of cords[2] and the products are given in terms of gallons of 82 per cent wood alcohol and pounds of 80 per cent acetate of lime. The three standard species are again given for comparison.

The relative yields from the species tested are quite different when compared on the cord basis and on the percentage weight basis. These differences are, of course, due to the large variation in weight per unit volume of the different woods. The two species of elm and the silver maple are much lighter woods than beech or hard maple, and therefore do not compare so favorably on the cord basis. The oaks and eucalyptus are appreciably heavier than the standard species, and consequently have a high relative value per cord.

[1] Compare tupelo gum, Bulletin 129.
[2] The weights per cord are calculated by multiplying by 90 the known weight per cubic foot of air-seasoned material of the species.

TABLE 2.—*Yields of commercial alcohol and acetate per cord of wood.*

Species.	Locality.	Yield of wood alcohol (82 per cent).			Yield of acetate of lime (80 per cent).			
		Heart-wood.	Slab-wood.	Mean heart and slab.	Heart-wood.	Slab-wood.	Mean heart and slab.	Weight per cord, 15 per cent moisture.
		Gallons.	*Gallons.*	*Gallons.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Beech	Indiana	11.8	10.9	11.4	301	335	318	3,785
Birch	Wisconsin	8.3	8.9	8.6	346	355	351	3,600
Hard maple	.....do	11.8	11.6	11.7	301	284	293	3,875
White elm	Pennsylvania	10.2	8.3	9.3	280	290	285	3,060
Slippery elm	Wisconsin	10.7	9.5	10.1	276	263	270	3,330
Silver maple	.....do	8.5	8.2	8.4	260	219	240	2,880
Green, blue, and yellow ash.	Tennessee and Missouri.	12.1	9.1	10.6	262	235	249	3,960
Black ash	Wisconsin	10.1	11.5	10.8	284	260	272	3,510
Green ash	Missouri		[1] 12.8		([1])	257		3,960
Chestnut oak [2]	Tennessee	8.1	8.8	8.5	287	291	290	4,140
Tanbark oak	California	11.4			397			4,068
Black oak	.....do		9.4	[1] 12.4		327	[1] 451	3,800 [1] 4,650
Swamp oak	Louisiana	9.5	8.3	8.9	278	309	294	3,960
Eucalyptus	California	10.5	13.2	11.9	325	377	351	4,950

[1] Limbs.
[2] In case of chestnut oak the mean is not the average, since the slab represented more runs than heart.

In yields of alcohol per cord, the different species of ash, tanbark oak, and eucalyptus are practically as good as beech and maple. Chestnut oak, swamp oak, slippery elm, and white elm (heartwood) did not compare so favorably with beech and hard maple, but all of them except chestnut oak gave higher yields than birch.

Tanbark oak, California black oak,[1] and eucalyptus are the only species in this group that gave as high yields of acetate of lime as the standard species, although swamp oak and chestnut oak gave practically as good yields as hard maple. Tanbark oak gave a higher yield of acetate than any other species so far tested. The remarkable yield of acetate from California black-oak limb wood is due in part to the very heavy wood. It must be remembered, however, that commercially a cord of limbs would contain much less solid wood than a cord of body wood and the yield would be reduced proportionately.

TABLE 3.—*Relative yields of commercial alcohol and acetate per cord.*

[Average yield from heartwood of beech, birch, and hard maple from Indiana and Wisconsin=100 per cent. Acetate=316 pounds; alcohol=10.63 gallons.]

Species.	Locality.	Alcohol.		Acetate.	
		Heart.	Slab.	Heart.	Slab.
White elm	Pennsylvania	96.0	78.1	88.6	91.8
Slippery elm	Wisconsin	100.7	89.3	87.3	83.2
Silver maple	.....do	80.0	77.2	82.3	69.3
Green, blue, and yellow ash	Tennessee and Missouri	113.7	85.6	82.9	74.4
Black ash	Wisconsin	94.7	108.6	89.9	82.3
Green ash	Missouri	[2] 120.7		[2] 81.3	
Chestnut oak	Tennessee	76.6	82.5	90.8	92.1
Tanbark oak	California	106.7		125.6	
Black oak	.....do	[2] 116.3	88.3	[2] 142.7	103.5
Swamp oak	Louisiana	89.2	78.4	88.0	97.8
Eucalyptus	California	99.0	124.1	102.8	119.3

[1] A more detailed discussion of the commercial possibilities of distilling the California oaks is given in Metallurgical and Chemical Engineering, Vol. XII, p. 623.
[2] Limbs.

The relative value of the species, obtained by taking the average of beech, birch, and maple heartwood as 100 per cent, is given in Table 3, and the same values are shown diagrammatically in figures 1 and 2.

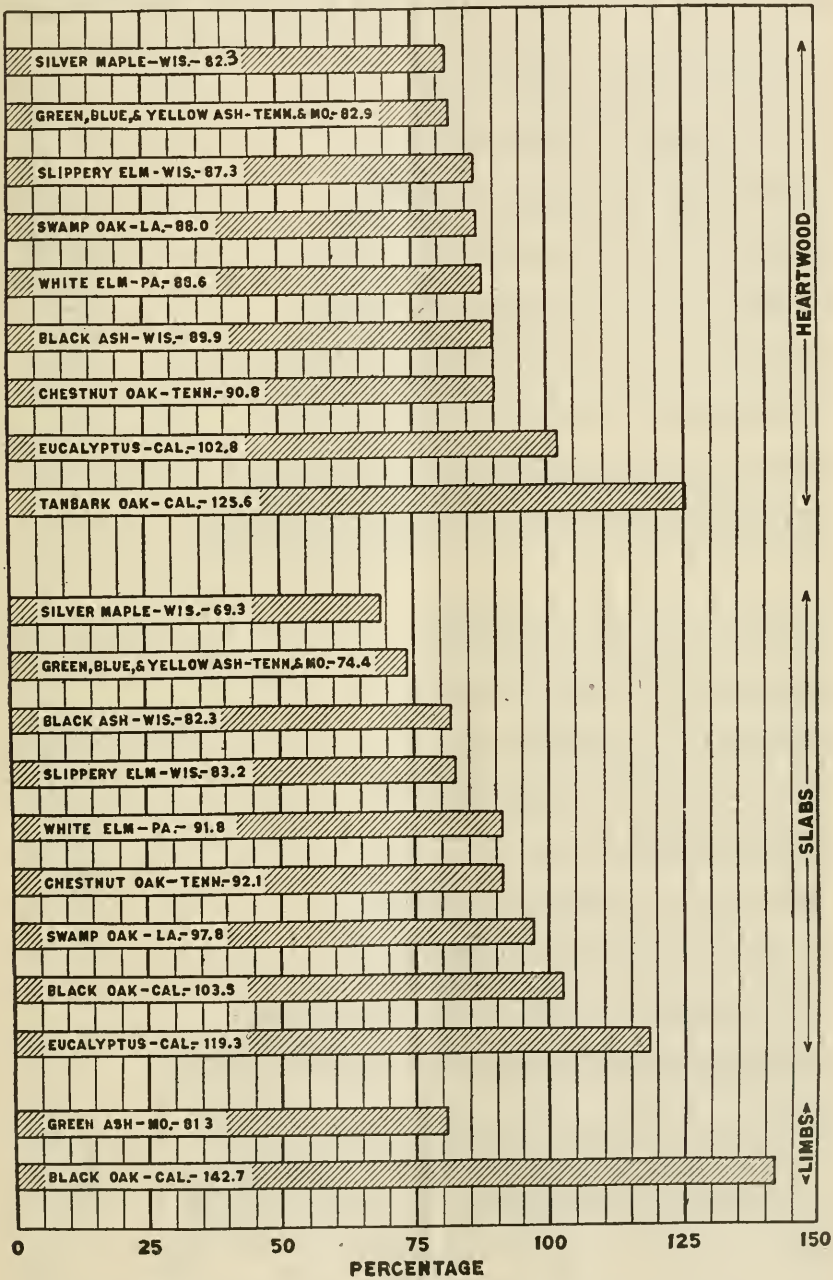

FIG. 1.—Relative yields of acetate of lime per cord. (Average yield from heartwood of beech, birch, and maple from Indiana and Wisconsin equals 100 per cent.)

In Bulletin 129 the averages for beech, birch, and maple included yields from heartwood and lumber. Later experiments on temperature control have shown that in these experiments yields from lumber were not strictly comparable with those from heartwood, and

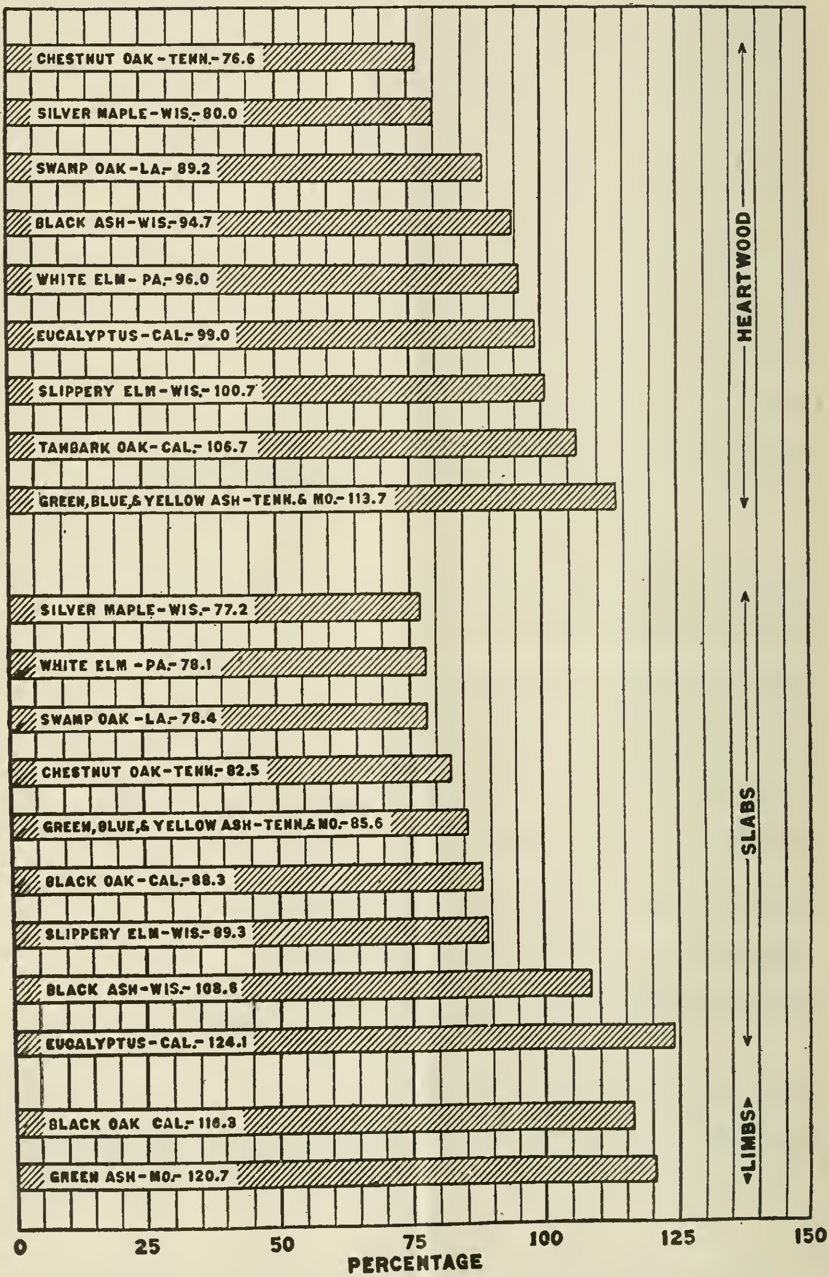

FIG. 2.—Relative yields of wood alcohol per cord. (Average yield from heartwood of beech, birch, and maple from Indiana and Wisconsin equals 100 per cent.)

are therefore omitted in this bulletin. The data from Bulletin 129 corrected to eliminate the yields from lumber are given in Table 4.

TABLE 4.—*Relative yields of commercial alcohol and acetate per cord.*

[Average yield from heartwood of beech, birch, and maple from Indiana and Wisconsin=100 per cent; acetate=316 pounds; alcohol=10.63 gallons.]

Species.	Locality.	Alcohol.		Acetate.	
		Heart.	Slab.	Heart.	Slab.
Beech	Indiana	111.0	102.6	95.3	106.0
Do	Pennsylvania	127.2	118.6	99.1	106.7
Birch	Wisconsin	78.2	83.7	109.5	112.4
Do	Pennsylvania	87.6	85.7	101.0	99.4
Hard maple	Wisconsin	111.0	109.3	95.3	89.9
Do	Pennsylvania	111.6	100.8	99.4	95.4
Red gum	Missouri	88.4	86.7	85.2	78.2
Chestnut	New Jersey	34.8	33.9	62.7	60.2
Hickory	Indiana	144.2	....	....	....
White oak	.....do	86.7	86.7	97.7	93.4
Do	Arkansas	86.7	95.2	83.0	85.2
Tupelo	Missouri	82.4	98.0	71.6	82.4

Elm and silver maple, which gave low yields of alcohol and acetic acid, also gave low yields of liquor per cord. The cost of recovery per cord would, of course, be somewhat dependent on the amount of pyroligneous acid to be refined.

The yields of charcoal and tar are only of relative interest. It was not possible in the laboratory tests to determine the value of these products, whose quality is only known in the wood-distillation industry in terms of commercial methods of distilling. In general, however, it is noted that the heavier woods give higher yields of charcoal.

PYROLIGNEOUS ACID, TAR, AND CHARCOAL.

The average yields of pyroligneous acid, tar, and charcoal expressed in pounds per cord are given in Table 5. The yields of pyroligneous acid are of interest mainly in connection with the cost of refining the products from a cord of wood.

TABLE 5.—*Average yields of pyroligneous acid, tar, and charcoal per cord.*

Species.	Locality.	Pyroligneous acid (based on oven-dry wood).			Charcoal.			Tar.			Weight of cord.
		Heart.	Slab.	Mean heart and slab.	Heart.	Slab.	Mean heart and slab.	Heart.	Slab.	Mean heart and slab.	
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Beech	Indiana	1,062	1,165	1,113.5	1,417	1,297	1,357	319	349	334	3,785
Birch	Wisconsin	1,152	1,159	1,155.5	1,315	1,284	1,299.5	325	285	305	3,875
Maple	.....do	1,120	1,061	1,090.5	1,341	1,515	1,428	418	310	364	3,600
White elm	Pennsylvania	946	997	971.5	1,065	1,055	1,060	322	295	309	3,060
Slippery elm	Wisconsin	984	913	948.5	1,180	1,275	1,228	279	205	242	3,330
Silver maple	.....do	920	809	864.5	1,030	1,115	1,072	302	201	252	2,880
Green, blue, and yellow ash.	Tennessee and Missouri.	1,162	990	1,076	1,410	1,575	1,492	390	270	330	3,960
Black ash	Wisconsin	1,070	1,040	1,055	1,162	1,234	1,198	348	276	312	3.510
Green ash	Missouri	......	......	[1]1,045	......	......	[1]1,388	.....	[1]346	.....	3,960
Chestnut oak	Tennessee	1,280	1,072	1,176	1,425	1,685	1,555	368	316	342	4,140
Tanbark oak	California	1,315	......	....	1,330	......	....	318	.....	.....	4,068
Black oak	.....do	......	1,125	[1]1,420	......	1,389	[1]1,640	.....	333	[1]413	3,800 [1]4,650
Swamp oak	Louisiana	1,089	1,024	1,056.5	1,598	1,630	1,614	251	307	279	3,960
Eucalyptus	California	1,405	1,500	1,452.5	2,065	1,900	1,982	166	377	271	4,950

[1] Limbs.

Where especially high yields of refined products are obtained, there is usually a large volume of crude liquor which must be handled to secure these products. Tanbark oak, California black oak, and eucalyptus all showed high yields of crude liquor per cord and also gave high yields of acetic acid and alcohol, as indicated in Table 2.
use of the manufactures from figures 1 and 2. The laboratory yields

COMMERCIAL DISTILLATION.

The results given in this bulletin can be best interpreted for the use of the manufacturer from figures 1 and 2. The laboratory yields of acetate of lime are over 50 per cent higher than those obtained in standard commercial practice, although the alcohol yields do not differ much from commercial yields.

Since the data are compared with the results of laboratory distillations of the standard species—beech, birch, and maple—they are entirely comparable on this basis. In the commercial interpretation of these diagrams, the average yields per cord from Wisconsin and Michigan beech, birch, and maple may be given as 10.5 gallons of 82 per cent crude wood alcohol and 185 pounds of gray acetate of lime. Using these yields as a basis, and taking the relations given in the diagrams, a simple calculation will give an actual cost value for judging the different forms and species for distillation. For example: Taking an average market value for acetate of lime as $1.75 per 100 pounds and 82 per cent alcohol at 26 cents per gallon, the value of these two products[1] from beech, birch, and maple in the commercial plant is, then, $3.24 for acetate plus $2.73 for alcohol, which equals $5.97 per cord. Comparing chestnut oak in figures 1 and 2, the calculation gives $\$3.24\times0.915^{2}+\$2.73\times0.796=\$5.14$. Chestnut oak is, then, obviously worth about 83 cents less per cord to the distillation plant than the standard species. The slabs alone are worth more than bodywood, a consideration of interest to the sawmill. Tanbark oak indicates a value of $\$3.24\times1.256+\$2.73\times1.067=\$6.98$ for alcohol and acetate, or with equal manufacturing and market conditions, a plant could stand a charge of $4.50 per cord for the raw material.

Of course, many other factors enter into the consideration of the value of any form or species of wood for distillation, but the relative value of the products examined would in each case be the primary consideration.

[1] In this particular calculation it is necessary to assume that the yields of charcoal would not vary greatly. If the calculation with acetate and alcohol indicated the value of the wood to be questionable, the charcoal could not be expected to bring up the result.

[2] Mean of heart and slab.

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HENRY S. GRAVES, Forester

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THE THEORY OF DRYING AND ITS APPLICATION TO THE NEW HUMIDITY-REGULATED AND RE-CIRCULATING DRY KILN.

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CONTENTS.

INTRODUCTION.

The problem of satisfactorily drying lumber without checking, honeycombing, or warping is one of very wide interest. Although an old problem, it has not yet reached an entirely satisfactory solution, especially with hardwood lumber. Even air drying, which is the slowest and what might be called the most conservative method of removing the moisture, is far from satisfactory for some species of wood. The drying of softwoods, or wood from coniferous trees, on the other hand, may be considered as having reached a fairly satisfactory solution. With few exceptions, the softwoods present no special difficulty to the lumber drier. The great trouble with the hardwoods lies in their relatively excessive and very unequal shrinkage. This is due largely to the structure of the wood. In softwoods the vertical elements are all of the same kind, regularly arranged and of approximately the same width (tangentially). The medullary rays also are very fine and regular. In hardwoods, on the other hand, the elements are very complex, varying in diameter in some species in the same section 20 to 30 times, and are often very crooked. Many woods, such as the oak, have large medullary rays, as

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well as very small ones, irregularly arranged. Consequently, strains are produced when the wood dries, which cause warping and checking. While air drying is undoubtedly the safest method, the process is ordinarily so slow, requiring a year or longer according to species and size, that forced "artificial" drying becomes a business necessity. Moreover, air drying is by no means always to be preferred to kiln drying from the standpoint of the quality of the product.

A correct understanding of the principles of drying is rare, and opinions in regard to the subject are very diverse. The same lack of knowledge exists in regard to dry kilns. The physical properties of the wood which complicate the drying operation and render it distinct from that of merely evaporating free water from some substance like a piece of cloth must be studied experimentally. It can not well be worked out theoretically.

The thermal process of the drying operation, however, is capable of exact theoretical analysis. It is the purpose of this article to interpret the conditions which exist in the various stages of the drying operation with respect to the heat quantities and the changes which occur in the drying medium, from a theoretical standpoint. The object of this analysis is to show the limiting conditions which may be approached, but can not be exceeded.

ELEMENTARY PRINCIPLES OF DRYING.

Before taking up the theoretical discussion, a few remarks upon the elementary principles of drying will be of assistance.

EVAPORATION REQUIRES HEAT.

In the first place, it should be borne in mind that it is the heat which produces evaporation and not the air nor any mysterious property assigned to a "vacuum." For every pound of water evaporated at ordinary temperatures approximately 1,000 British thermal units of heat are used up, or "become latent," as it is called. This is true whether the evaporation takes place in a vacuum or under a moderate air pressure. If this heat is not supplied from an outside source it must be supplied by the water itself (or the body being dried), the temperature of which will consequently fall until the surrounding space becomes saturated with vapor at a pressure corresponding to the temperature which the water has reached; evaporation will then cease. The pressure of the vapor in a space saturated with water vapor increases rapidly with increase of temperature. At a so-called vacuum of 28 inches, which is about the limit in commercial operations, and in reality signifies an actual pressure of 2 inches of mercury column, the space will be saturated with vapor at about 101° F. Consequently, no evaporation will take place in such a vacuum unless the water be warmer than 101° F., provided there is no air leakage. The qualification in regard to air is necessary, for the sake of exactness, for the following reason: In any given space the total actual pressure is made up of the combined pressures of all the gases present. If the total pressure ("vacuum") is 2 inches, and there is no air present, it is all produced by the water vapor (which saturates the space at 101° F.); but if some air is present and the total pressure is still maintained at 2 inches, then there must be less vapor present, since the air is producing part of the pressure and the space is no longer saturated at the given temperature. Consequently further evaporation may occur, with a corresponding lowering of the temperature of the water, until a balance is again reached. Without further explanation it is easy to see that but little water can be evaporated by a vacuum alone without addition of heat and that the prevalent idea that a vacuum can of itself produce evaporation is a fallacy. If heat be supplied to the water, however, either by conduction or radiation, evaporation will take place in direct proportion to the amount of heat supplied, so long as the pressure is kept down by the pump.

At 30 inches of mercury pressure (one atmosphere) the space becomes saturated with vapor and equilibrium is established at 212° F. If heat be now supplied to the water, however, evaporation will take place in proportion to the amount of heat supplied, so long as the pressure remains that of one atmosphere, just as in the case of the vacuum. Evaporation in this condition, where the vapor pressure at the temperature of the water is equal to the gas pressure on the water, is what is commonly called "boiling," and the saturated vapor entirely displaces the air under continuous operation. Whenever the space is not saturated with vapor, whether air is present or not, evaporation will take place, by boiling if no air be present or by diffusion under the presence of air, until an equlibrium between temperature and vapor pressure is resumed.

Relative humidity is simply the ratio of the actual vapor pressure present in a given space to the vapor pressure when the space is saturated with vapor at the given temperature. It matters not whether air be present or not. One hundred per cent humidity means that the space contains all the vapor which it can hold at the given temperature—it is saturated. Thus at 100 per cent humidity and 212° F. the space is saturated, and since the pressure of saturated vapor at this temperature is one atmosphere, no air can be present under these conditions. If, however, the total pressure at this temperature were 20 pounds (5 pounds gauge), then it would mean that there was 5 pounds air pressure present in addition to the vapor, yet the space would still be saturated at the given temperature. Again, if the temperature were 101° F., the pressure of saturated vapor would be only 1 pound, and the additional pressure of

14 pounds, if the total pressure were atmospheric, would be made up of air. In order to have no air present and the space still saturated at 101° F., the total pressure must be reduced to 1 pound by a vacuum pump. Fifty per cent relative humidity, therefore, signifies that only half the amount of vapor required to saturate the space at the given temperature is present. Thus at 212° F. temperature the vapor pressure would only be 7½ pounds (vacuum of 15 inches gauge). If the total pressure were atmospheric, then the additional 7½ pounds is simply air. "Live steam" is simply saturated water vapor at a pressure usually above atmospheric. We may just as truly have live steam at pressures less than atmospheric, at a vacuum of 28 inches for instance. Only in the latter case its temperature would be lower, viz, 101° F. Superheated steam is nothing more than water vapor at a relative humidity less than saturation, but is usually considered at pressures above atmospheric, and in the absence of air. The atmosphere at, say, 50 per cent relative humidity really contains superheated steam or vapor, the only difference being that it is at a lower pressure and temperature than we are accustomed to think of in speaking of superheated steam, and it has air mixed with it to make up the deficiency in pressure below the atmosphere.

Two things should now be clear: That evaporation is produced by heat and that the presence or absence of air does not influence the amount of evaporation. It does, however, influence the rate of evaporation, which is retarded by the presence of air. The main things influencing evaporation are, first, the quantity of heat supplied and, second, the relative humidity of the immediately surrounding space.

IMPORTANCE OF CIRCULATION.

A piece of wood may be heated in three ways—(1) by convection of the air and vapor or other gases, (2) by conduction through some body in contact therewith, and (3) by radiation. Of these three ways, only the first is ordinarily available for use in heating a pile of lumber, since by either of the other two methods only the outside surface of the pile could be heated; hence the necessity of a large and thorough circulation of air. Drying in a vacuum would be feasible if there were some means of conveying the heat to the wood. A single stick can be readily dried in a vacuum, as it can receive heat on all sides by radiation from the walls of a steam-jacketed cylinder; but this is impracticable when it comes to any quantity of lumber, except in the case of superheated vapor alone, as will be shown later, since only the outer surface or the outside boards would receive the heat in this way and the inside ones would not dry. Even an approach to a perfect vacuum, however, is not reached in commercial apparatus. Moreover, the heat convection in a vacuum of 26 inches or less is almost as rapid as under ordinary air pressure.[1] The viscosity of the gas is a factor in the convection through small spaces, such as between the layers of lumber, and as this is almost as great at low pressures as at atmospheric pressure, it follows that the actual circulation would nevertheless be very much cut down. Thus, by drawing a vacuum the means of heating the wood is reduced. Later on it will be shown, however, that drying at low pressure in absence of air should give the highest theoretical heat efficiency, but the volume of vapor required is excessive.

RATE OF EVAPORATION CONTROLLED BY HUMIDITY.

It is essential, therefore, to have an ample supply of heat through the convection currents of the air; but in the case of wood the rate of evaporation must be controlled, else checking will occur. This can be done by means of the relative humidity. It is clear now that when the air—or, more properly speaking, the space—is completely saturated no evaporation can take place at the given temperature. By reducing the humidity, evaporation takes place more and more rapidly.

Another bad feature of an insufficient and nonuniform supply of heat is that each piece of wood will be heated to the evaporating point on the outer surface, the inside remaining cool until considerable drying has taken place from the surface. Ordinarily in dry kilns high humidity and large circulation of air are antitheses to one another. To obtain the high humidity the circulation is either stopped altogether or greatly reduced, and to reduce the humidity a greater circulation is induced by opening the ventilators or otherwise increasing the draft. This is evidently not good practice, but as a rule is unavoidable in most kilns. The humidity should be raised to check evaporation without reducing the circulation.

ELEMENTARY PRINCIPLES OF HYGROMETRY.

RELATIVE HUMIDITY AND DEW POINT.

It is necessary to know something of hygrometry in order to understand the drying operations. As stated before, at any given temperature the same quantity of water vapor is required to saturate a given

[1] Bottomly gives for radiation of a bright platinum wire to a copper envelope, at different air pressures, the temperature of the inclosure being 16° C. and the difference in temperature 408° C. expressed in the heat lost in c. g. s. units per square centimeter of inclosure (Smithsonian Table 250):

At 740 mm. absolute pressure	0.8137
At 42 mm. absolute pressure	.7591
At 0.44 mm. absolute pressure	.2683
At 0.01 mm. absolute pressure	.0539

These figures evidently include radiation and convection. They show comparatively small change at pressures above 42 millimeters of mercury, which corresponds to a vacuum of about 28.4 inches.

space, whether any air is present or not; and the pressure of the vapor is the same in both cases. The total pressure (as registered by the gauge) will not be the same, however, since if air is present its pressure is added to that of the vapor. It is really the space and not the air which is saturated. For instance, at 101° F. it takes about 20 grains of vapor to saturate a cubic foot of space. If no air be present, there will be a pressure of vapor only, which will be about 1 pound, or a vacuum of 28 inches. If this is open to the atmosphere the air will rush into the space until the total pressure will be one atmosphere, or about 15 pounds. There will then be 1 pound of pressure produced by the vapor, as before, and 14 pounds of air pressure. The space will still be saturated, if the temperature is kept at 101° F. If this is now heated to 160° F. and open to the atmosphere so that the total pressure is kept constant, the ratio of the pressures of vapor and air will also remain the same; there will still be 1 pound due to vapor and 14 pounds due to the air. (The weights in the cubic foot of space of both will decrease, due to expansion by heat.) At 160° F., however, it requires 91 grains of vapor to saturate a cubic foot of space, and its pressure is nearly 5 pounds (absolute). Consequently, the relative humidity at 160° F. of this space will be one-fifth, or 20 per cent. Conversely, if this air and vapor at 20 per cent relative humidity and 160° F. temperature is cooled to 101° F., all at the same atmospheric pressure, the space will again become saturated, and any further cooling will cause precipitation or condensation. This is called the dew point; that is, 101° F. is the dew point of air with 20 per cent humidity at 160° F. In Forest Service Bulletin 104, "Principles of Drying Lumber at Atmospheric Pressure and Humidity Diagram," a humidity diagram is given for solving all problems of this nature. The concave curves on this diagram are simply curves of constant vapor pressure with change of temperature and relative humidity, and the grains of vapor per cubic foot, at saturation or the dew point, are given in numerical figures. From this it is seen that the dew point determines the relative humidity when the temperature is raised, or vice versa. If we take saturated air at known temperature and heat it up any given desired amount, the resulting relative humidity is thereby determined. This is the principle upon which the humidity regulation depends in a new kiln designed by the writer.[1] It is also evident that whenever air is cooled below its dew point condensation takes place. This is the principle of the condenser. There are a number of kilns which have made use of this principle to dry the air. Pipes are used for the condensers and cold water is circulated through the pipes. The same thing can be accomplished by a spray of cold water in place of the pipes, provided all the fine mist is subsequently removed from the air, or even by a sur-

[1] For a description of this kiln see page 10.

face of cold water. In the new kiln a fine spray of water is used instead of a condenser. This has the additional advantage that when the water is heated above a certain temperature (the temperature of the wet bulb in a wet-and-dry bulb hygrometer) it will humidify the air. By simply changing the temperature of the spray the air may be supplied at any desired humidity.

INSTRUMENTS FOR MEASURING HUMIDITY.

A common instrument used for measuring humidity is the wet-and-dry bulb hygrometer or "psychrometer." This consists of two thermometers mounted side by side, the bulb of one of which is covered by a silk cloth or wick which dips into a vessel of water. This should be placed in a fairly strong draft of air. The evaporation from the "wet bulb" reduces its temperature below that of the dry bulb, and the rate of this evaporation, and consequently the temperature of the wet bulb, depends upon the relative humidity in the air. By noting the two temperatures of the dry and the wet bulb thermometers the relative humidity can be determined by tables which have been carefully worked out by the Weather Bureau.[1]

In the humidity diagram in Forest Service Bulletin 104 the values are expressed in curves (the convex series of curves on the diagram), by means of which the relative humidity may be read off directly without numerical calculations. This instrument is probably the simplest reliable means for determining humidity. There are instruments which read directly from a hand on a dial, the motion of the hand being produced by the swelling of vegetable or animal tissues. These are very convenient but fragile and not to be depended upon. The most direct way of determining humidity is, of course, to determine the dew point. This may be accomplished by gradually cooling a bright surface, as polished metal, in contact with the moving air, until a mist is precipitated thereon. Special interest attaches to the wet-and-dry bulb hygrometer for the reason that the wet wood in the dry kiln is actually in the same condition as the wet bulb. It is affected in the same way. The actual temperature of the wood, while it is moist, is therefore that of the wet bulb, provided there is sufficient circulation.

TYPES OF KILNS.

There are two distinct ways of handling lumber in kilns. One way is to place the load of lumber in a chamber where it remains in the same place throughout the operation, while the conditions of the drying medium are varied as the drying progresses. This is the compartment kiln or stationary method. The other is to run the lumber in one end of the chamber on a wheeled truck and gradually

[1] See Psychrometer Tables by Marvin, Bulletin 235 of United States Weather Bureau.

move it along until the drying process is completed, when it is taken out at the opposite end of the kiln. An attempt is usually made in these kilns to maintain one end moist and the other end dry. This is known as the "progressive" type of kiln, and is the one most commonly used in large operations. It is the least satisfactory of the two, however, where careful drying is required, since the conditions can not be so well regulated and the temperatures and humidities are apt to change with change of wind. The compartment method can be arranged so that it will not require any more kiln space or any more handling of lumber than the progressive type. It does, however, require more intelligent operation, since the conditions in the kiln must be changed as the drying progresses. With the progressive type the conditions, once established, remain the same.

To obtain draft or circulation three methods are in use—by forced draft or a blower usually placed outside the kiln, by ventilation, and by internal circulation and condensation. A great many patents have been taken out on different methods of ventilation, but in actual operation few work exactly as intended. Frequently the air moves in the reverse direction for which the ventilators were planned. Sometimes a condenser is used in connection with the blower and the air is recirculated. It is also—and more satisfactorily—used with the gentle internal-gravity currents of air.

Many patents have been taken out for heating systems. The differences among these, however, have more to do with the mechanical construction than with the process of drying. In general, the heating is either direct or indirect. In the former steam coils are placed in the chamber with the lumber, and in the latter the air is heated by either steam coils or a furnace before it is introduced into the kiln.

Moisture is sometimes supplied by means of free steam jets in the kiln or in the entering air; but more often the moisture evaporated from the lumber is relied upon to maintain the humidity necessary. In the new humidity-regulated kiln the humidity is controlled directly. The majority of kilns make no attempt whatever to regulate this all-important factor beyond retaining an indeterminate amount at the beginning of the operation and drying the air, either by condensers or by ventilation at the end.

Other methods of drying in vacuum and in various gases have been tried from time to time.

DRYING BY SUPERHEATED STEAM.

There is still another type of kiln which is not included in the former classification, viz, that using superheated steam. What this term really signifies is simply water vapor in the absence of air in a condition of less than saturation. Such kilns are, properly speaking, vapor kilns, and usually operate at atmospheric pressure, but may be used at greater pressures or at less pressures. As stated before, the vapor present in the air at any humidity less than saturation is really "superheated steam," only at a lower pressure than is ordinarily understood by this term, and mixed with air. The main argument in favor of this process seems to be based on the idea that steam is moist heat. This is true, however, only when the steam is near saturation. When it is superheated it is just as dry as air containing the same relative humidity. For instance, steam at atmospheric pressure and heated to 248° F. has a relative humidity of only 50 per cent and is just as dry as air containing the same humidity. If heated to 306° F., its relative humidity is reduced to 20 per cent; that is to say, the ratio of its actual vapor pressure (one atmosphere) to the pressure of saturated vapor at this temperature (five atmospheres) is 1:5, or 20 per cent. Superheated vapor in the absence of air, however, parts with its heat with great rapidity and finally becomes saturated when it has lost all of its ability to cause evaporation. In this respect it is more moist than air when it comes in contact with bodies which are at a lower temperature. When saturated steam is used to heat the lumber it can raise the temperature of the latter to its own temperature, but can not produce evaporation unless, indeed, the pressure is varied. Only by the heat supplied above the temperature of saturation can evaporation be produced. This subject will be taken up again in the theoretical analysis.

IMPORTANCE OF PROPER PILING OF LUMBER.

The efficiency of the drying operation depends a great deal upon the way in which the lumber is piled, especially when the humidity is not regulated. From the theory of drying just discussed it is evident that the rate of evaporation in kilns where the humidity is not regulated depends entirely upon the rate of circulation, other things being equal. Consequently, those portions of the wood which receive the greatest amount of air dry the most rapidly, and vice versa. The only way, therefore, in which anything like uniform drying can take place is where lumber is so piled that each portion of it comes in contact with the same amount of air.

In the Forest Service kiln, where the degree of relative humidity is used to control the rate of drying, the amount of circulation makes little difference, provided it exceeds a certain amount. It is desirable to pile the lumber so as to offer as little frictional resistance as possible and at the same time secure uniform circulation. If circulation is excessive in any place it simply means waste of energy but no injury to the lumber.

The best method of piling is one which permits the heated air to pass through the pile in a somewhat downward direction. The natural tendency of the cooled air to descend is thus taken advantage of in assisting the circulation in the kiln. This is especially important when cold or green lumber is first introduced into the kiln. But even when the lumber has become warmed the cooling due to the evaporation increases the density of the mixture of the air and vapor. Table 3 shows analytically that the spontaneous cooling of the mixture produced by the evaporation alone increases its density. This fact is of great significance, and the method of piling lumber in the Forest Service kiln takes advantage of this principle.

THEORY AND DESCRIPTION OF THE FOREST SERVICE KILN.

The humidities and temperatures in the piles of lumber are largely dependent upon the circulation of air within the kiln. The temperature and humidity within the kiln, taken alone, are no criterion of the conditions of drying within the pile of lumber if the circulation in any portion is deficient. It is possible to have an extremely rapid circulation of the air within the dry kiln itself and yet have stagnation within the pile, the air passing chiefly through open spaces and channels. Wherever stagnation exists or the movement of air is too sluggish the temperature will drop and humidity increase, perhaps to the point of saturation.

When in large kilns the forced circulation is in the opposite direction from that induced by the cooling of the air by the lumber there is always more or less uncertainty as to the movement of the air through the piles. Even with the boards placed edgewise, with stickers running vertically, and with the heating pipes beneath the lumber, it was found that although the air passed upward through most of the spaces it was actually descending through others, so that very unequal drying resulted. While edge piling would at first thought seem ideal for the freest circulation in an ordinary kiln with steam pipes below, it in fact produces an indeterminate condition; air columns may pass downward through some channels as well as upward through others, and probably stagnate in others. Nevertheless, edge piling is greatly superior to flat piling where the heating system is below the lumber.

From experiments and from a study of conditions in commercial kilns the idea was developed of so arranging the parts of the kiln and the pile of lumber that advantage might be taken of this cooling of the air to assist the circulation. That this can be readily accomplished without doing away with the present features of regulation of humidity by means of a spray of water is clear from figure 1, which shows a cross section of the improved humidity-regulated dry kiln.

In the form shown in the sketch a chamber or flue B runs through the center near the bottom. This flue is only about 6 or 7 feet in height and, together with the water spray F and the baffle plates D D, constitutes the humidity-control feature of the kiln. This control of humidity is effected by the temperature of the water used in the spray. This spray completely saturates the air in the flue B at whatever predetermined temperature is required. The baffle plates D D are to separate all entrained particles of water from the air, so that it is delivered to the heaters in a saturated condition at the required temperature. This temperature is, therefore, the dew point of the air when heated above, and the method of humidity control may therefore be called the dew-point method. It is a very simple matter by means of the humidity diagram,[1] or by a hydrodeik, to determine what dew-point temperature is needed for any desired humidity above the heaters.

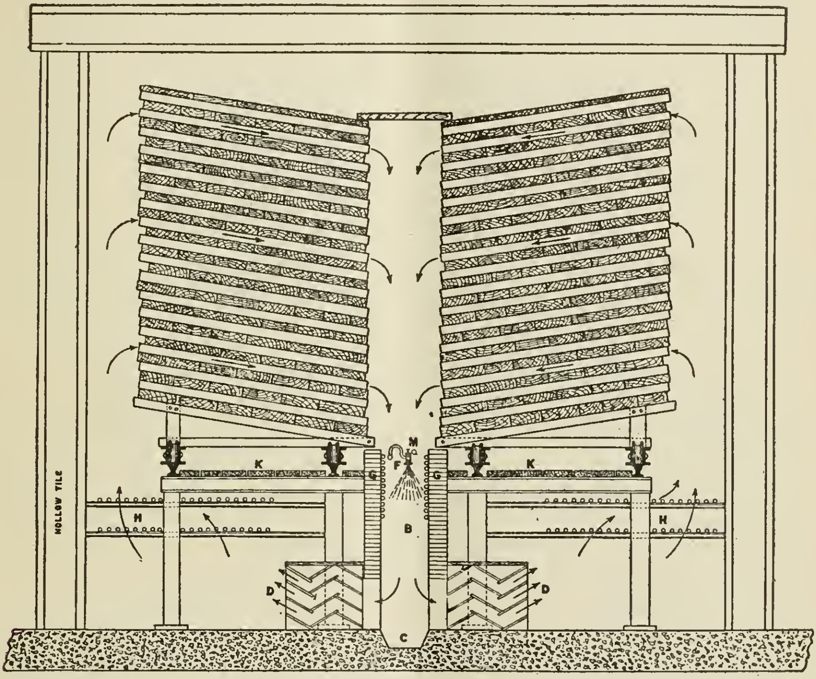

FIG. 1.—Diagrammatic section of improved dry kiln with spray chambers in center. Double-truck form.

Besides regulating the humidity the spray F also acts as an ejector and forces a circulation of air through the flue B. The heating system H is concentrated near the outer walls, so as to heat the rising column of air. The temperature within the drying chamber is controlled by means of any suitable thermostat, actuating a valve on the main steam line. The lumber is piled in such a way that the stickers slope downward toward the center.

M is an auxiliary steam spray pointing downward for use at very high temperatures. C is a gutter to catch the precipitation and

[1] Forest Service Bulletin 104, "Principles of Drying Lumber at Atmospheric Pressure and Humidity Diagram," Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 5 cents. Lumber World Review, Feb. 10. 1915.

conduct it back to the pump, the water being recirculated through the sprays. G is a pipe condenser for use toward the end of the drying operation. K is a baffle plate for diverting the heated air and at the same time shielding the under layer of boards from direct radiation of the steam pipes.

The operation of the kiln is simple. The heated air rises above the pipes H H at the sides of the piles of lumber. As it comes in contact with the piles portions of it are cooled and pass downward and inward through the layers of boards into the space between the con-

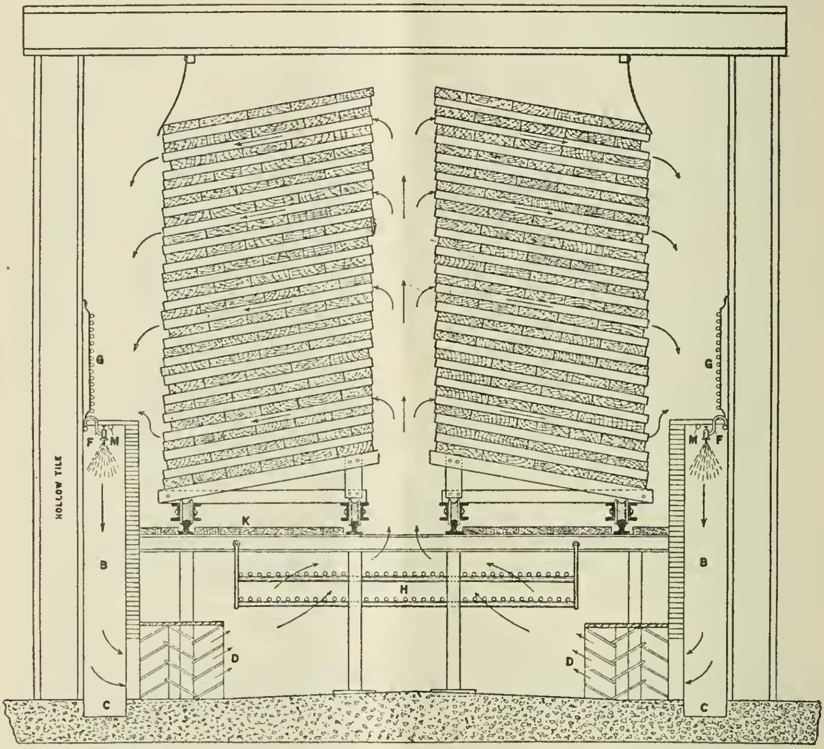

FIG. 2.—Diagrammatic section of improved dry kiln with spray chambers on sides. Double-truck form.

densers G G. Here the column of cooled air descends into the spray flue B, where its velocity is increased by the force of the water spray. It then passes out from the baffle plates to the heaters and repeats the cycle.

Various modifications of this arrangement may be made. For instance, a single-track kiln may be used. This form would be represented by simply dividing the diagram vertically into two parts by extending the wall G (on the left side) upward to represent the outer wall, and erasing the part to the left of this line. Or, again, the spray chambers may be kept on the sides as shown in figure 2. The lumber would then slope in the opposite direction with respect to the center of the kiln and the air would rise in the center and descend on the sides.

One of the greatest advantages of this natural circulation method is that the colder the lumber when placed in the kiln the greater is the movement produced, under the very conditions which call for the greatest circulation—just the opposite of the direct-circulation method. This is a feature of the greatest importance in winter, when the lumber is put into the kiln in a frozen condition. One truck load of lumber at 60 per cent moisture may easily contain over 7,000 pounds of ice.

In the matter of circulation the kiln is, in fact, self-regulatory—the colder the lumber the greater the circulation produced, with the effect increased toward the cooler and wetter portions of the pile.

Preliminary steaming may be used in connection with this kiln, but experiments indicate that ordinarily it is not desirable, since the high humidity which can be secured gives as good results, and, being at as low a temperature as desired, much better results in the case of certain difficult woods like oak, eucalyptus, etc.

This kiln has another advantage in that its operation is entirely independent of outdoor atmospheric conditions, except that barometric pressures will affect it slightly.

THEORETICAL DISCUSSION OF EVAPORATION.

In considering the drying effect of vapor alone (superheated steam) and of air mixed with the vapor, one very significant fact must be noticed. Saturate vapor alone in cooling and in order to remain saturate must absorb heat. Its specific heat is negative, so that the only way it can heat a body is by condensation. It is, therefore, incapable of producing evaporation. When air is present with the saturate vapor, however, the air can supply some of this heat, according to the pressure of the air present, so there will be less condensation.

Still more important is the fact that when air is present with the vapor sufficient heat can be supplied to the body being dried by means of the air without greatly superheating the vapor, thus keeping a high relative humidity and at the same time supplying a sufficient amount of heat to carry on the evaporation. With vapor alone (superheated steam) a relatively high degree of superheating, which means a correspondingly low relative humidity, is required in practice in order to supply the necessary heat for evaporation, after the material has become heated through to the temperature of the saturated vapor at the pressure used. Remember that the temperature of the wet wood corresponds to that of the wet bulb in the hygrometer when air is present, but very nearly to the dew point in the presence of superheated vapor alone.

EVAPORATION IN THE ABSENCE OF AIR.

In vapor alone, no air being present, evaporation from a surface of water takes place at the dew point, but when the water is intimately contained in other substances the temperature must be higher than the dew point. If air is present it retards the rate of evaporation from a free surface of water, so that the surface is warmer than the dew point, depending upon the degree of relative humidity in the air. While the surface of wood is wet its temperature will not rise above that of the wet bulb in the presence of air, nor above the dew point in superheated vapor alone. As it becomes drier, however, its temperature will rise, due to its affinity for retaining moisture. In the former condition there is no danger of too rapid drying, but in the latter condition, if the humidity is too low or the superheat too high, the drying from the surface may become more rapid than the rate at which the moisture is transmitted from the center, and casehardening results.

In considering the manner in which drying takes place in superheated steam, suppose the pressure is atmospheric and that a wet piece of wood has been heated in saturated steam to 212° F. No evaporation will take place until additional heat is added. Now, suppose steam superheated to 232° F. or 20° of superheat is introduced. The portion immediately in contact with the surface of the wet wood will be cooled to 212° F., and in so doing it will vaporize a certain portion of water from the surface. As the specific heat of this steam is, in round terms, one-half, and as it requires about 1,000 thermal units to vaporize one unit of water, to vaporize a single molecule of water at 212° F. will require contact of 100 of the molecules of superheated steam at 232° F. We will then have 101 molecules of steam in the saturated condition at 212° F. Evaporation must then cease unless this saturated steam is replaced by some fresh superheated steam. Evaporation from a free surface of water in the absence of air (in superheated steam) always takes place at the boiling point (which in this case is the same as the dew point). If, however, there is a deficiency of water in the wood more heat will be required to separate it and to vaporize it, and evaporation will take place at a higher temperature than the dew point. In fact, evaporation may cease altogether in the superheated steam, and a higher degree of superheating be required (which is equivalent to a lower humidity) to get the moisture out of the wood. In the case of a surface of free water the rate of evaporation depends entirely upon the amount of heat transmitted to the water, whether by increasing the circulation or by increasing the degrees of superheat. In the latter case, when the moisture is intimately contained in the wood, the rate depends largely upon the relative humidity.[1] There is a balance between what might be termed the retentive or attractive property of the wood, "hygroscopicity," and the tendency of the moisture to vaporize. It is the difference between the tension of the vapor at the higher temperature of the wood and the tension actually existing in the space surrounding the wood. This retentive property increases as the wood becomes drier and decreases as it approaches the wet condition. Experiments indicate that generally it is nearly inversely proportional to the amount of moisture remaining in the wood.

EVAPORATION WHEN AIR IS PRESENT.

When air is present with the superheated steam or water vapor the conditions are quite different. Vaporization of a particle from the surface of the free water is retarded by the air pressure, so that the temperature of the water may be raised above the dew point.[2]

The air now, as well as the vapor, conducts heat to the water, so that the rate of evaporation at given pressures depends not alone on the quantity of heat supplied (by circulation and degree of superheating) but upon the relative amounts of vapor and air present. That is to say, the lower the relative humidity the greater is the rate of evaporation at a given temperature and pressure. The temperature of the water will correspond to that of the wet bulb, and not to that of the dew point. When the wood becomes partially dried its temperature will rise, as in the case of superheated steam, and it may be heated even above the boiling point at the given pressure without giving up all of its moisture, provided there is some vapor in the air.

CONCLUSIONS AS TO DRYING IN VAPOR ALONE AND IN AIR AND VAPOR.

Thus it is seen that the rate of drying may be controlled by the relative humidity, provided there be sufficient circulation to supply the heat required. In the case of steam alone, the rate of drying, as just shown, depends upon the quantity of circulation as well as the degree of superheating. Hence the conclusion follows that moist air, with ample circulation, should give more uniform drying throughout than superheated steam, which varies with the rate of circulation in each portion.

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[1] In using the term relative humidity as applied to superheated steam it is understood to mean the ratio of the actual vapor pressure to that of the pressure of saturated vapor at the given temperature, as explained before.

[2] In reality what probably happens is that the layer of air in immediate contact with the water becomes saturated and has a higher vapor pressure corresponding to the temperature of the surface of the water, and the air retards the diffusion of this vapor. The temperature of the water, however, can not exceed the boiling point for the given pressure, at which point the conditions must become the same as those for superheated steam alone, since then the air will become entirely displaced by the water vapor.

But the chief difficulty with superheated steam at or above atmospheric pressure is the high temperature to which the material must be subjected, the minimum with very wet wood being 212° F., and increasing as the wood dries. Below atmospheric temperatures, costly apparatus is required for operating at a vacuum, and the heating medium is attenuated, requiring an excessive volume of vapor to be circulated if the danger is to be avoided of the wood, as it becomes dry on the surface, being heated too high. Instead of a vacuum the same result can be obtained by combining air with the vapor, in which case the air makes up the deficiency of pressure. For instance, a vacuum of 28 inches, which is about the extreme in mechanical operations, will give an absolute vapor pressure of about 1 pound and a temperature of 101° F. for saturated conditions. Precisely the same value for the vapor occurs if saturated air at 101° F. and atmospheric pressure is used instead, in which case the additional heating capacity of the air present is also available. There would then be in a cubic foot of space vapor pressure of 1 pound (nearly) per square inch and 13.7 pounds of dry air pressure. This amount of vapor would weigh 0.0029 pound and the air 1/15.2 or 0.0658 pound (15.2 being the volume in cubic feet of 1 pound of dry air at 13.7 pounds pressure and 101° F. temperature).

HEATING CAPACITIES OF AIR AND VAPOR IN MIXTURE.

The heating capacity of the vapor in this cubic foot of space, in falling 1 degree, from 102° F. to 101° F., is $.0029 \times .42$[1]$=.00122$ B. t. u., as before, while that of the air present is $.0658 \times .237 = .0156$ B. t. u., or more than ten times that of the vapor present. The total heating capacity of 1 cubic foot of the mixture, in falling 1 degree, from 102° F. to 101° F., is then the sum of these two, viz, .01682 B. t. u. The latent heat of evaporation at 101° F. being 1044, it will require the heat given up by $1044/.01682 = 62,206$ cubic feet of the mixed air and vapor falling 1 degree, from 102° F. to saturation at 101° F., to evaporate 1 pound. This is very much less than that required for vapor alone, which, as will be shown farther on, is 829,433 cubic feet. In fact, the quantity in volume is less than that of dry air alone at 212° F. and one atmospheric pressure (69,000), as figured farther on. If the vapor is superheated, say, to 112° F., its pressure remaining the same as before, this is simply equivalent, so far as the vapor is concerned, to air at atmospheric pressure with a relative humidity of less than saturation. In this case the relative humidity would be the pressure of the actual vapor—0.972 pound per square inch—divided by the pressure which the vapor would have if it were saturated at 112° F., viz, $.972/1.34 = 73$ per cent humidity.

[1] The specific heat of superheated vapor at this temperature is 0.421 as given by Thiesen.

It should now be evident that superheated vapor is the same thing as moist air with the air removed. The same effects upon the material to be dried are produced in both cases, as far as the vapor is concerned; but in the case of moist air, the effect of the air is added to that of the vapor. The same laws apply to the vapor, whether the air is present or absent. The air conveys heat, but by its presence retards the diffusion of the vapor, and consequently retards the rate of evaporation.

RELATIVE HEATING CAPACITIES OF AIR AND VAPOR.

To compare the relative heating capacities of dry air and of superheated vapor, the following deductions are made: The specific heat of water vapor at a pressure of one atmosphere is 0.475; that is to say, 1 pound of superheated steam in falling 1° F. gives up 0.475 British thermal unit. To evaporate 1 pound of water at 212° F., therefore, will require the heat given up by 966 (latent heat at 212° F.)$\div$.475=2034 pounds of steam falling 1 degree. At 212° F. the volume per pound is 26.78 cubic feet; therefore, $2034\times26.78=54{,}470$ cubic feet of superheated steam falling 1 degree are required to evaporate 1 pound of water. The specific heat of dry air is 0.237 and the volume of 1 pound is 16.93 (0.05907 pound per cubic foot) at 212° F. and atmospheric pressure. Therefore, to evaporate 1 pound of water at 212° F. (966 B. t. u.) will require the heat given up by $966\times\frac{16.93}{.237}=69{,}000$ cubic feet of dry air falling 1 degree. Thus it is seen that the heating capacity per unit of volume of superheated steam at atmospheric pressure is but little greater than that of dry air at the same temperature and pressure, in the ratio of 69,000 to 54,470, or about 5 to 4. At temperatures above 212° F. and the same pressure of one atmosphere a greater volume is necessary to produce the same effect, since the gas and vapor expand with temperature, but the ratio of the heating capacity of superheated steam and dry air remains very nearly the same. The specific heat of vapor increases slightly at higher temperatures. Thus, figuring in a similar manner, it will be found that at five atmospheres pressure (59 pounds gauge) the heating ratio of equal volumes of steam and air is 1.42 to 1, and at 1 pound absolute pressure or a vacuum of 28 inches, it is 1.104 to 1. The volume of steam at five atmospheres pressure and 306° F. in falling 1 degree necessary to evaporate 1 pound of water at this pressure and temperature is 10,336 cubic feet, and at a vacuum of 28 inches at 101° F. it is 829,433 cubic feet.

Thus it is seen that there is but little advantage, from the point of view of the volume of gas to be moved, in the use of superheated steam over that of dry air.

In this discussion a cubic foot of space has been used as the basis of the calculations. In analyzing the heat quantities in the drying operation it will be easier to use 1 pound of dry air as a basis, with its accompanying moisture, and follow it through its various stages. Its volume will therefore not remain fixed, but will change with every change in temperature, and consequently the degree of saturation produced by a definite amount of moisture accompanying it will depend upon the volume which it occupies.

THEORETICAL ANALYSIS OF HEAT QUANTITIES.

For this purpose the simplest way will be to follow a pound of dry air through a drying cycle as a basis for computations. While in reality the vapor does not enter the air like water in a sponge, but occupies the same space whether air is present or not, we may, for convenience, conceive of a pound of air as containing a certain amount of vapor, which, in reality, means that the space occupied by a pound of dry air under given conditions contains a certain amount of vapor.

VAPOR AND AIR IN MIXTURE.

As already explained, the total pressure always is the sum of the individual pressures of the air alone plus the vapor alone. Thus we may speak of a pound of air as being wholly or partially saturated with vapor, meaning that it is the space occupied by the pound of air which is in this condition of vapor. If a pound of air said in this sense to contain a given weight of vapor is heated a given amount under a pressure of one atmosphere, both air and vapor will expand the same amount, so that at the new temperature both will occupy the same relative amount of space; the pound of air, however, will still contain the same weight of vapor. The amount of vapor contained in a pound of air alone, when it is saturated, can not be used as the divisor in obtaining the relative humidity when compared to the amount of vapor actually contained in the pound of air alone, because when the air is saturated the pressure of the air alone will have been reduced, corresponding to the increase in the vapor pressure (since the sum of the two make up one atmosphere), so that for a pound of air a much greater space is required, and, consequently, an equivalently greater weight of vapor to occupy this larger space. For relative humidity it is necessary to compare the weights of vapor which occupy the same amount of space when partially or wholly saturated, or, better still, to compare the vapor pressures.

CYCLE IN DRYING OPERATION OF 1 POUND OF AIR.

In following the pound of dry air through its cycle of operation, let the air enter the heater either from outside or from the spray chamber at temperature t_1, and let it contain d_1 pounds of vapor. (See fig. 3.) After passing through the heater both the air and the vapor are raised to the temperature t_2. Each pound of air still contains d_1 pounds of moisture, since the vapor expands to the same extent as the air if no vapor is added or subtracted during the heating from t_1 to t_2. In passing through the lumber, the air and vapor become cooled to t_3, and an amount of moisture, w, is added from the evaporation, so that the pound of air at temperatures t_3 now contains $d_3=(d_1+w)$ pounds of moisture. Thence they either escape into the outer air, as in a ventilating kiln, or pass into the spray chamber, where the heat added by the heater and the extra amount of moisture w is removed from the pound of air into the spray water, and is returned at the initial temperature t_1 saturated to repeat the cycle. The changes in total pressure will be so slight that they may be neglected, and the whole operation considered to take place at a uniform pressure of one atmosphere. Let r equal the specific heat of air at constant pressure, and s that of superheated vapor. These will be taken as 0.237 and 0.475, respectively. Then the quantity of heat imparted to the pound of air and its accompanying d_1 pounds of vapor by the heater is (1), $(.237+d_1\times.475)\ (t_2-t_1)$ and the amount of heat given up in evaporating the water w is (2), $(.237+d_1\times.475)\ (t_2-t_3)$. The amount of water evaporated is $w=(d_3-d_1)$. Now the heat required to evaporate the water w in continual operation will be that required to raise it from its initial temperature to the evaporating point, plus the latent heat of vaporization at this point; also the heat necessary to raise the temperature of the wood alone the same amount. As the latter is small, it will be neglected. Suppose that the initial temperature of the outside air and of the wet wood is 32° F. Then the heat required is simply the total heat H of w pounds of vapor at the temperature t_3 (nearly).[1]

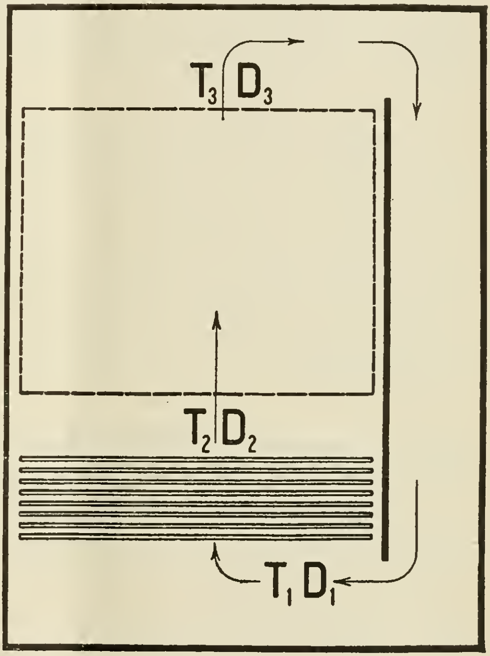

Fig. 3.—Diagrammatic plan of drying cycle.

[1] Evaporation will actually take place at the temperature of the wet bulb if the air is not saturated, after which the vapor is superheated to t_3.

Hence (3), $(.237+d_1\ .475)\ (t_2-t_3)=wH=(d_3-d_1)\ H$ or $\frac{t_2-t_3}{d_3-d_1}=\frac{H}{.237+d_1\ .475}$. In this equation t_2 is a known quantity, being dependent upon the kind and condition of the material being dried. d_1 is known, being the weight of moisture of the outside air per pound of dry air, or the weight required to saturate 1 pound of air in the spray kiln at the temperature t_1. H is known approximately (but not exactly, since its value varies with t_3, or more properly with the wet-bulb temperature), and may at first be assumed for some temperature between t_2 and t_1, and afterwards be correctly assigned. t_3 and d_3 are the unknown quantities required. If the air is to be considered saturated at t_3, then t_3 and d_3 are dependent variables, their equation being that of the curve of saturation for water vapor. As the equation is complex, their relative values can be more readily obtained from a table of saturated vapor, and successive values substituted in equation (3) until the equation is fulfilled. Having thus determined t_3 approximately, the correct value for H may be inserted and the more exact value of t_3 determined. This has been done by E. Hausbrand in "Drying by Means of Air and Steam"[1] for diffrent temperatures of t_1 and t_2, as well as for different humidities and pressures.

EFFICIENCY OF OPERATION.

With no air present—that is to say, with water vapor alone under a so-called "vacuum," or with "superheated steam" at pressures of one atmosphere or greater—all the heat may be utilized in evaporating the moisture, the leaving and entering temperatures being the same and the pressure constant. With air present, however, and the pressure constant, it follows that if the entering air is saturated the leaving air must be at a higher temperature, in order that it may contain the additional vapor at the same pressure. Thus in raising the temperature of the air leaving the lumber a greater amount of heat is required than that utilized in evaporation.

There is another combination of conditions possible in which the temperature at exit may be the same or even less than that of the entering air or vapor. With air present this is only possible by decreasing the pressure below that of the entering saturated air. In this case the heat supplied may be even less than the theoretical amount required for vaporization, and the theoretical efficiency as reckoned by temperatures is more than 100 per cent. The advantage gained here is at the expense of the heat energy in the departing air and vapor, being somewhat analogous to the case of the condenser in a steam engine. The gain in heat is from the fact that the enter-

[1] Translation from the German by Wright. Published by Scott Greenwood & Sons, 1901.

ing air is at a higher temperature than the leaving air. If the entering air is not saturated, a similar condition is possible, since some evaporation may take place without necessitating a higher temperature of the leaving air.

From the foregoing it might be concluded that the use of a vacuum or of superheated steam would be the most economical way in which to dry materials. In practice, however, the vacuum has certain disadvantages, as explained heretofore, the chief one being the greater volume of vapor required and the difficulty of producing a uniform circulation of vapor at high attenuation. The other drawback is the expense of the apparatus and difficulty of operation at pressures other than atmospheric. With superheated steam the temperature is too high for most woods.

CONCRETE EXAMPLES OF RELATIONS OF HEAT QUANTITIES.

To illustrate the relations of these quantities under the various conditions, let us take a concrete example where the initial temperature of the air is 32° F. and the air is saturated both at the entrance and upon leaving. This is heated to 158° F. and then passed through the material to be dried. The volume of the gas required at the temperature of 158° F. and the theoretically least possible expenditure of heat required to evaporate 1 pound of water from an initial temperature of 59° F. at various pressures are given below in Table 1.

TABLE 1.—*Volume of gas required at a temperature of 158° F. and the theoretically least possible expenditure of heat required to evaporate 1 pound of water from an initial temperature of 59° F. at various pressures.*

Absolute pressures.	Volume.	Total heat required.
	Cubic feet.	*B. t. u.*
1½ atmospheres	695	2,010
1 atmosphere=760 mm. of mercury	876	1,692
500 mm. of mercury, partial vacuum	1,247	1,578
250 mm. of mercury, partial vacuum	2,121	1,346
Using steam alone superheated from 140° to 158° F. at pressure of 148 mm. of mercury, corresponding to saturated conditions at 140° F	16,821	1,125

The minimum theoretical expenditure of heat, as here calculated, has no direct bearing on the efficiency of any method of drying lumber, since the physical requirements of the lumber may, and generally do, demand conditions totally incompatible with the highest theoretical heat efficiency. They apply directly only to the evaporation of a free body of water, irrespective of length of time required and with no radiation losses. The calculations are useful, however, in showing the limiting values of the efficiency which it is possible to attain under the conditions which have otherwise been found most suitable for drying the lumber in question.

It is instructive to know the highest possible theoretical efficiency in evaporating a pound of water under given conditions, considering no losses by radiation or otherwise. For this purpose Table 2 has been worked out, assuming the water to start with an initial temperature of 59° F. and to evaporate at the temperature t_3, which is the temperature of the leaving air. The efficiency here expressed is the ratio of the total heat of water vapor at t_3 above 59° F. divided by the least possible expenditure of heat necessary to evaporate it under the assumed conditions of the entering and leaving air at atmospheric pressure. When the temperature t_1 of the entering air approaches that of the heated air t_2—that is, when a high humidity is used—the calculations become very uncertain, since the quantity of air called for under the assumed conditions approaches infinity, while the temperature differences between t_1 and t_3 become infinitesimal.

The minimum volume of air required to evaporate 1 pound of water is also given in Table 2.

TABLE 2.—*Maximum possible theoretical heat efficiency of evaporation under given conditions (t_1, t_2, h_1, h_3) at atmospheric pressure (760 mm.).*

Entering air.		After heating.		Leaving air.		Heat consumed to evaporate 1 pound of water from initial temperature of 59° F.	Total heat of 1 pound of vapor at t_3 above initial temperature of 59° F.	Minimum volume of air required.	Efficiency H÷G.
t_1	h_1	t_2	h_2	t_3	h_3				
A	B	C	D	E	F	G	H	J	K
° F.	Per ct.	° F.	Per ct.	° F.	Per ct.	B.t.u.	B.t.u.	Cubic ft.	
32	100	95	11	65	75	2,353	1,074	2,163	0.457
59	100	95	31	76	75	2,100	1,078	3,426	.514
32	100	158	2	84	75	1,911	1,080	993	.565
59	100	158	6	92	75	1,715	1,082	1,126	.631
86	100	158	13	107	75	1,556	1,087	1,402	.698
32	100	212	0+	97	75	1,758	1,084	694	.617
59	100	212	2	103	75	1,572	1,086	731	.690
86	100	212	4	114	75	1,422	1,089	796	.767
32	100	95	11	84	25	6,136	1,080	5,738	.176
32	100	158	2	110	25	2,972	1,088	1,495	.366
86	100	158	13	141	25	4,869	1,098	4,385	.225
32	100	212	0+	126	25	2,352	1,093	930	.457
86	100	212	4	146	25	2,166	1,099	1,206	.507
32	100	95	11	60	100	1,974	1,073	1,836	.544
59	100	95	31	70	100	1,679	1,076	2,733	.641
86	100	95	74	88	100	1,476	1,081	9,725	.733
32	100	158	2	79	100	1,692	1,079	876	.636
86	100	158	13	99.5	100	1,390	1,085	1,329	.781
140	100	158	63	140.9	100	1,119	1,098	3,879	.981
32	100	212	0+	90	100	1,582	1,082	625	.684
86	100	212	4	106	100	1,350	1,087	721	.804
176	100	212	47	176.5	100	1,130	1,108	2,002	.972
IN WATER VAPOR ALONE.									
140	100	158	63	140	100	1,097	1,097	16,418	1.00
212	100	230	71	212	100	1,119	1,119	3,657	1.00
212	100	320	16	212	100	1,121	1,121	664	1.00

GENERALIZATION.

A study of the theoretical heat relations, as shown by Hausbrand's tables, makes possible the following generalizations:

1. With t_2 constant and entering air saturated, the expenditure of heat is less, the higher the temperature, t_1, of the entering air.

2. With t_1 constant, the expenditure of heat is less, the higher the temperature, t_2, to which the air is heated.

3. Other things being the same, the heat expenditure increases rapidly with reduction in humidity of the emergent air.

4. Other things being the same, the heat expenditure is less, the lower the humidity of the entering air.

5. Other things being the same, the expenditure of heat increases with increase of pressure.

6. With water vapor in the absence of air, the theoretical efficiency becomes 100 per cent.

In regard to the weights and volumes of air required, the following observations are obtained, with entering air saturated:

With t_2 constant, both the weights and volumes of air required to evaporate 1 pound of water increases with increase of the initial temperature, t_1, of the entering air.

With t_1 constant, both weights and volumes decrease with increased temperature, t_2, of the heated air.

With the emergent air only partially saturated, the weights and volumes increase with decrease of relative humidity in the emergent air.

CONCLUSIONS AS TO EFFICIENCY OF OPERATION.

From this analysis of the heat equations the following conclusions as regards the efficiency of the drying may be drawn: [1]

1. The air should be heated to the highest temperature compatible with the nature of the material to be dried.

2. The air upon leaving the apparatus should be as near saturation as practicable.

3. The temperature of the entering air should be as high as possible.

APPLICATION OF ANALYSIS TO THE WATER SPRAY OR CONDENSING KILNS.

The above deductions apply to any form of moist-air kiln. The following have more especially to do with the Forest Service water spray humidity regulated kiln.

The amount of heat absorbed by the spray water and the condensed moisture aside from losses through the kiln walls is the

[1] It should be noted, as stated above, that these deductions apply solely to the evaporating process alone, from a theoretical standpoint, and do not take into consideration heat losses through the kiln walls or through extraneous conditions; nor do they signify what is the condition best suited for conducting the drying operation from the standpoint of the physical effect upon the wood.

difference between the total heat in the saturated air as it leaves the lumber at t_3 and the total heat in the air at t_1. It is, in fact, the amount of heat given up by the coils, since the air is brought back to its initial state in the cycle and the water evaporated from the wood is added to the spray water. Hence the amount of heat removed in water at a temperature t_1 is (4), $G(t_2-t_1)\times(c+sd_1)$, when G is the weight of dry air in the mixture required to evaporate 1 pound of water. c and s are the specific heats of the air and vapor. Of this the amount $G(t_3-t_1)$ $(c+sd_1)$ represents the loss not accounted for in the latent heat of the pound of water which has been evaporated and is taken up by the spray water. The maximum possible thermal efficiency is therefore (5), $\frac{(t_2-t_3)}{(t_2-t_1)}$, if just enough air is circulating to give up all its available heat to the evaporation of the water so that it leaves the lumber in a saturated condition. From equation (2) and (3) the value of t_3 is determined for any given values of t_1 and t_2. These values may be most readily obtained from the tables given by Hausbrand, before referred to. t_1 and t_2 are arbitrary values determined entirely by the physical conditions of the material to be dried.

In actual operation, however, the efficiency will be much less than this maximum, since the air leaving will not be saturated, and a much larger quantity of air will need to pass through the material than the minimum indicated by the equation. If no evaporation takes place, all the heat will be used in heating and cooling the circulating medium. The total heat used per pound of air will then be (t_2-t_1) $(c+sd_1)$, and this will go simply to heating the spray water.

COMPARISON OF EFFICIENCY.

Comparing the theoretical efficiency of the condensing with that of the ventilating type of kiln, it will be seen that under identical running conditions its efficiency is much greater, because the initial temperature t_1 is very much higher. Let the temperature of the outside air be 32° F., so that the water has to be raised from 32° F. to the temperature of evaporation an dthen evaporated. Let the air leaving the lumber be three-fourths saturated, 75 per cent humidity. Also let $t_1=113°$ and $t_2=140°$, giving a relative humidity of 48 per cent. Then d_1 for 1 pound of saturated air at 113 is 0.0653 pound. Substituting those values in equation (3) it is found that $t_3=125°$ and $d_3=0.06889$. Since $w=d_3-d_1$, the number of pounds of air required to evaporate 1 pound of water is $G=\frac{1}{w}=\frac{1}{d_3-d_1}=279$, which contains $279\times0.0653=18.2$ pounds of vapor. The pressure of the saturated vapor alone at 113° is 71.4 mm. of mercury; hence that of the air alone is $760-71.4=688.6$ mm. of mercury. The volume occupied by 1 pound of dry air at 113° and a pressure of 688.6 mm. of mercury is 16 cubic feet (more exactly 15.921), which must be the same as that occupied by the 0.0654 pound of vapor present in the pound of air. As 279 pounds of air are required with its inherent 18.2 pounds of vapor, the volume of air, or combined air and vapor, is $15.921 \times 279 = 4{,}442$ cubic feet at 113°. At 125° this will occupy 4,535 cubic feet.

The total heat consumed is $279\ (0.237 + 0.0653 \times 0.475) \times (140 - 113) = 2{,}019$ B. t. u.,[1] of which the useful work has been the total latent heat of 1 pound of vapor above 32° F. evaporated at 116° F. (the wet-bulb temperature) and superheated to 125° F.=1,122 B. t. u. This should be the same as the heat given out by the air and superheated vapor in cooling from 140° F. to 125° F., $279\ (0.237 + 0.0653 \times 0.475) \times (140 - 125) = 1{,}122$. The thermal efficiency is $\frac{t_2 - t_3}{t_2 - t_1} = \frac{140-125}{140-113} = 55.6$ per cent. Also $\frac{1122}{2019} = 55.6$ per cent.

Compare this first with a ventilating kiln in which the air enters saturated at 32° F., is heated to 140° F., and leaves at 75 per cent humidity, escaping to the outer air. We then have

$t_1 = 32°$, $d_1 = .00387$ pound per pound of air

$t_2 = 140°$

t_3 = calculated = 80.2, and d_3 at 75 per cent humidity = .01692.

The quantity of air required to evaporate 1 pound of water is:

$$G = \frac{1}{.01692 - .00387} = 76.6 \text{ pounds.}$$

This air contains $76.6 \times .00387 = 0.296$ pound of vapor. The total heat consumed is:

$$76.6\ (.237 + .00387 \times .475)\ (140 - 32) = 1{,}969 \text{ B. t. u.}$$

The thermal efficiency is $\frac{140-80}{140-32} = 55.6$ per cent, which happens to be the same as in the condensing kiln, but examination will show at once that the two cases are not analogous. In the condensing kiln the

[1] Another way of arriving at this result is to compare the total heats; thus, in the vapor at 125° and 75 per cent saturation:

Total heat in the air alone at $125° = 279 \times 0.237\ (125 - 32)$ equals	6, 149
Total heat in saturate vapor at the dew point of 115° (75 per cent humidity at $125°) = 279 \times 0.06889 \times 1117$ equals	21, 491
Superheating this vapor from its dew point of 115° to $125° = 279 \times 0.06889 \times 0.475 \times 10$ equals	91
Total at 125°	27, 731

At the initial stage, 113°:

Total heat in air$= 279 \times 0.237\ (113 - 32)$ equals	5, 356
Total heat in saturate vapor at $113° = 279 \times 0.0653 \times 1116.4$ equals	20, 339
Total heat at 113°	25, 695

The difference, $27{,}731 - 25{,}695 = 2{,}036$ B. t. u., is the heat added to the air. This should be the same as before, namely, 2,019, the difference being in inaccuracy of the constants used.

humidity after heating to 140° F. was 48 per cent; in the other kiln it is only 3 per cent, an extremely low amount.

For a correct comparison, the condition of the air entering the lumber should be the same in both cases, namely, it is necessary to raise the humidity in the ventilating kiln from 3 per cent to 48 per cent. This can be done by allowing live steam to escape into the heated air sufficient to saturate it at 113° F., the dew point for 48 per cent humidity. Now, if 1 pound of dry air saturated at 32° F. is heated to 113° F. it will still contain its original weight of vapor, namely, 0.00387 pound; but to saturate a pound of air at 113° F. requires 0.0653 pound of vapor; consequently, the difference between this and 0.00387 or 0.06143 pound of vapor must be added for each pound of air at 113° F., in order to make the two cases comparable; they are then exactly alike, and we shall have for our kiln, to recapitulate, as before—

$t_1=113°$ saturated
$t_2=140°$ humidity 48 per cent
$t_3=125°$ humidity 75 per cent.

Number of pounds of air required to evaporate 1 pound of water at 115° from initial temperature of 32°=279—

Total heat required=2,019 B. t. u.
Heat lost [1] 2,019−1,122=897 B. t. u.

In the ventilating kiln, on the other hand, we shall have by comparison:

$t_1=32°$ saturated.
$t_2=140°$ at 3 per cent humidity.
$t_3=125°$ humidity 75 per cent.
h_2=heat in vapor added to raise the humidity

to saturation at 113° F.; 0.0614 pound are required per pound of air. The total heat in saturate vapor at 113° above 32°=1,117 B. t. u. per pound; 1,117×.0614=68.58 B. t. u. required per pound of air. There are 279 pounds of dry air required as in the other case. 68.5×279=19,134 B. t. u., which must be added as vapor.

K_2=heat required to raise temperature of the air and vapor from 32° to 113°=279 (.237+.00387×.475) (113−32°)=5,396 B. t. u.

Therefore, in this case the total heat which must be given to the air to evaporate 1 pound of water is—

	B. t. u.
Heat given by coils to raise the air from 32° to 113° equals	5, 396
Heat given by coils to raise saturate air from 113° to 140° as before equals	2, 019
Heat supplied in vapor equals	19, 134
Total heat required	26, 549
Heat lost (provided it all escaped to the air) 26,549 minus 1,122 equals	25, 427

[1] In the spray kiln this is not in reality lost, since part is utilized in producing the circulation and all the remainder is recovered in the spray water. It is simply a transfer of heat from lumber to spray water.

Compared to the loss in the Forest Service kiln, as just shown, of only 897 B. t. u., this would be enormous. It would mean an efficiency of only $\frac{1122}{25427}=4.41$ per cent. The assumption, however, that it all escapes to the outside air is not carried out in practice in moist air kilns, but instead a large proportion of this is returned by internal circulation, and only a small amount escapes into the air. It is not possible in the latter case to calculate the theoretical efficiency, since there is no means of knowing what portion of the heat is returned in the recirculation within the kiln. The analysis is instructive, however, in showing what enormous heat losses are possible in a ventilating kiln. In no case can the theoretical efficiency of the ventilating equal that of the Forest Service kiln when operating under identical conditions within the drying chamber.

INCREASE IN DENSITY PRODUCED BY EVAPORATION.

TABLE 3.—*Increase in density of mixture of air and vapor produced by the spontaneous cooling of the mixture from the evaporation of moisture as it passes through the lumber.*

Entering air.		After heating before entering lumber.			Leaving lumber.		Weight of 1 c. c. of mixture in grams.	
t_1.	h_1.	t_2.	h_2.	Dew point.	t_3.	h_3.	Entering at t_2h_2.	Leaving at t_3h_3.
° *F.*	*Per cent.*	° *F.*	*P. ct.*	° *F.*	° *F.*	*Per cent.*		
32	100	158	1.8	32	78.8	100	0.0010264	0.0011658
32	100	158	1.8	32	110.5	25	.0010264	.0011057
86	100	158	13	86	99.5	100	.0010126	.0011094
86	100	158	13	86	140.5	25	.0010126	.0010394
140	100	158	64	140	140.9	100	.0009525	.0009779
140	100	158	64	140	151.7	75	.0009525	.0010154
86	100	212	14	86	105.8	100	.0009310	.0010915
86	100	212	14	86	146.3	25	.0009310	.0010255
176	100	212	47	176	176.5	100	.0007820	.0008221

The weights are given in grams per cubic centimeter of the mixture. The independent variables which may be assumed at choice are (1) the temperature of the entering air t_1; (2) the relative humidity of the entering air h_1; (3) the temperature to which the air is heated before it enters the lumber t_2; and (4) the degree of saturation of the air leaving the lumber, h_3. From these, h_2, t_3, and the volumes and weights of the air and vapor are determined.

METHOD USED IN CALCULATING TABLE 3.

1. The temperature, t_3, of the air leaving the lumber is determined first, as for Table 1. The dew point must also be determined in order to determine the vapor pressure.

2. The following equation gives the value of the density (grams per c. c.) of the mixture of air and vapor:

$$d=\frac{B-0.378\,e}{760}\times\frac{.00129305}{1+.003670\,t}.$$[1]

B=total barometric pressure in millimeters of mercury.

e=pressure of the vapor in the mixture.

t=temperature Centigrade of the mixture.

.00129305 is the weight in grams of 1 c. c. of dry air at 0° C. pressure 760 mm. under gravity at 45° latitude and sea level. The figure .003670 is the coefficient of thermal expansion of air at 760 mm.

The first fractional expression may be explained as follows:

Let d_1=density of dry air at B–e mm. pressure.

d_v=density of vapor at e mm. pressure.

Then $d=d_1+d_v$. The air pressure alone is B–e and

$$d_1=d_0\,\frac{B-e}{760}.$$

$$d_v=.622\times d_0\times\frac{e}{760}.$$

when .622 is the density of vapor compared to air at 760 pressure.

$$\text{Whence } d=d_0\left\{\frac{B-e}{760}+\frac{.622\times e}{760}\right\}=d_0\left\{\frac{B-378e}{760}\right\}$$

Knowing the values t_2 and t_3 and the vapor pressures at these two points (pressures at the dew points) the values of d_2 and d_3 are obtained from the above equation.

It will be noted that in every case chosen in Table 3 the density increases due to the evaporation, hence the tendency of the air is to descend as it passes through the pile of lumber.

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[1] See Smithsonian Meteorological Tables, Tables 83 to 86.

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INTRODUCTION.

During the past few years a large number of requests for information on the control of decay in building and factory timbers have reached the United States Department of Agriculture. In many instances the cases reported have involved serious losses, often running into the thousands of dollars.

The rapidly rising interest in the question on the part of the public may be attributed to two general causes: (1) The greater publicity being given to this work in the Department of Agriculture, particularly through the activities of the Office of Investigations in Forest Pathology of the Bureau of Plant Industry and the Forest Products Laboratory of the Forest Service, and (2) the increasing use of timber less resistant to decay, which has become very marked during the past decade.

As a preliminary to an investigation into the prevalence of decay in building timbers, with the prime object of securing some basis for the effective control of such losses, a field study covering about seven months' active work was undertaken during 1914 to determine the conditions under which lumber and structural timbers are stored, for it is a well-known fact that timber infected with wood-destroying fungi during storage may be the direct cause of outbreaks of rot in buildings when such timber is placed in situations favorable to decay.

On account of the many failures in timber in important structures during recent years,[1] such an investigation is of the highest importance, both from the standpoint of owners and contractors and from that of the timber interests themselves.

The writer has encountered a number of instances where he was informed that wood has been replaced by steel or concrete for no other reason than the failure of locally available timber to withstand decay. An increasing use of these structural materials is bound to occur unless the lumber industry takes steps to improve the quality of its product for the North American market, and the first step in this process of regeneration lies in the better sanitation of lumber storage yards, so as to remove the danger of directly transferring fungous infections from the lumber dealer to the consumer.

During the course of this study a large number of sawmills and wholesale and retail lumberyards were visited in the eastern half of the United States. The region comprised 10 States along the Atlantic coast from Maine to Florida, all of the Gulf States, and the Central States of Arkansas, Iowa, Illinois, and Wisconsin. In addition to a personal inspection of the yards, much valuable information was obtained directly from the operators.

CAUSE OF DECAY IN TIMBER.

Decay in timber is almost exclusively due to the action of fungi, the greater part of the destruction being referable to one of the higher groups of these organisms, namely, the Hymenomycetes. In the life cycle of these fungi there are two distinct phases of development: (1) The vegetative stage (mycelium) and (2) the fruiting stage.

MYCELIUM.

The mycelium consists of microscopic threadlike filaments, usually branched, which penetrate the wood either by traversing the natural longitudinal passages, such as the pores, resin canals, or cell cavities, or by passing through the walls or through the pits in the walls of the wood fibers or tracheids (Pl. I, fig. 1). The mycelium also invades the pith rays, which contain a great abundance of food mate-

[1] In this connection, see the report by F. J. Hoxie, entitled "Dry Rot in Factory Timbers," 34 p., 19 fig., Boston, 1915, published by the Inspection Department of the Associated Factory Mutual Fire Insurance Companies, Boston, Mass.

rials readily available to the fungus and whose walls are thinner than those of the wood fibers and hence more readily penetrated.

The growth of the mycelium is conditioned by four factors: (1) The presence of satisfactory food supplies, (2) a suitable amount of moisture in the wood, (3) a temperature favorable for growth, and (4) at least a small supply of air to furnish the necessary oxygen.

Food supplies.—The mycelium, being a living, growing plant, must have nourishment for growth, and so utilizes for this purpose various constituents of the wood substance. These consist of the different compounds which go to make up wood tissue, the celluloses and ligno-celluloses being utilized as well as sugars, starches, and certain organic acids. To break down the woody tissues, which are chemically very complex, and thus render them assimilable to the fungus, certain imperfectly understood chemical substances (enzyms or ferments) are secreted by the organism. These act upon the wood substance, reducing it to simpler nutritive compounds. A number of these ferments have been isolated and studied by various investigators and their physiological and chemical action determined. They are quite specific in their action; different substances which enter into the composition of wood require different ferments to disorganize them. In general, however, the wood-destroying fungi are well supplied with the ferments necessary to produce serious disintegration of most of the constituents of woody tissues.

Moisture.—A considerable amount of moisture is necessary for rapid decay. Timber in an air-dry condition during dry weather will not ordinarily be affected, but during periods of rainy weather, when the atmospheric humidity is high, fungous infections may become serious. In highly humid stagnant air a surface development of mycelium (Pl. I, fig. 2) is possible, but under conditions of free air circulation the surface is usually kept too dry for this to occur, although the interior of large timbers may still retain sufficient moisture for decay to progress within them.

Temperature.—Wood-destroying fungi can maintain themselves over rather wide ranges of temperature, but have an optimum for most rapid development within comparatively narrow limits. According to German investigations *Merulius lachrymans* (Wulf.) Fr. has an optimum between 65° and 72° F. (18° and 22° C.); *Coniophora cerebella* (Pers.) Schröt. (=*C. puteana* (Schum.) Fr.) between 72° and 79° F. (22° and 26° C.), and *Lenzites sepiaria* (Wulf.) Fr. between 82° and 90° F. (28° and 32° C.).

Growth below these points is often considerably retarded, while a rise of 4 to 8 degrees above the optimum often causes total inhibition of growth or even death, as in the case of *Merulius lachrymans*, which is very sensitive to temperature changes above the optimum.

Air.—Under ordinary conditions the air supply within and surrounding the timber is amply sufficient for decay. Fungi develop best in still air in closed spaces, but this is due to the greater humidity rather than to air requirements, for a good air circulation dries the timber to a point unfavorable to the development of the organisms.

In the case of timber thoroughly saturated with water, however, so that the cell cavities are filled with the liquid, decay is prevented entirely through lack of sufficient oxygen.

FRUITING BODIES.

Fruiting bodies are an expression of fungous activity within the wood. They form only after decay has well started. They appear at the surface in the form of single or imbricate shelves or brackets, leathery or waxy incrustations, or, in a few cases, as mushrooms (Pl. I, fig. 3) with central or eccentric stems bearing an expanded cap at the top.

The fruit bodies of the many fungi which cause decay in timber may vary in color from white through reds and yellows to dark brown or blackish. The consistency or texture is also highly variable, from fleshy to tough and leathery, and occasionally hard and woody. In some species the under side, or outer surface where the fungus is spread out as a crust (resupinate), is smooth (Stereum, Corticium, Peniophora, Coniophora (frequently warted)). In other cases, the under side, or the outer surface where resupinate, bears numerous pores (Polyporus, Poria (Pl. II, fig. 5), Merulius, Trametes, Daedalea, Fomes). Still other species have platelike gills on the under side (Schizophyllum, Lentinus, Lenzites). Occasionally, forms with distinct spines (Pl. I, fig. 4) or teeth are encountered (Hydnum). Various other species are illustrated in Plates III to X.

HOW WOOD-DESTROYING FUNGI SPREAD.

There are two general methods by which wood-destroying fungi spread from infected to sound timber: (1) By a direct overgrowth of mycelium from an infected stick to adjoining or near-by timber, and (2) by the blowing about of spores produced by the fruit bodies or by the mycelium.

Infections by mycelium.—In wholly or partially inclosed moist spaces, such as are often found in the basements of buildings, in mines, or beneath low, poorly ventilated lumber piles, the mycelium finds sufficient moisture in the air to allow it to develop on the surface of timbers, and in this way may progress along the timber for considerable distances. Such may be the case also where timber is close piled; the writer has records where severe infections have thus passed during rainy weather from the bottom upward through piles 12 to 15 feet high. In lumber storage sheds or in the base of close piles the mycelium of several species of fungi has frequently been observed developing in great abundance, not alone on the moist foundations and lower layers of lumber (Pl. II, fig. 1), but also spreading profusely on the soil (Pl. II, figs. 2 and 3).

With some species of wood-destroying fungi the mycelium within infected timber may remain alive for long periods, even under air-dry conditions, a fact which makes the use of infected timber in building operations a dangerous procedure. As an example, we have the experimental evidence advanced by Bayliss [1] that the mycelium of *Polystictus versicolor* in wood can survive a period of four years under the dry conditions of a herbarium.

Infections by spores.—The chief purpose of spore formation in fungi, just as in seed formation in ordinary green plants, is the perpetuation of the species through reproduction. Spores serve the two-fold purpose of tiding the fungus over unfavorable periods and of allowing its rapid spread under favorable growth conditions. Nature is lavish in her methods, and the number of spores produced is often enormous. For instance, Buller [2] computed from partial counts that each pore on the under side of *Polyporus squamosus* produced in the course of a few hours an average of 1,700,000 spores, or a total of over eleven billion for the entire under surface of a fruit body having an area of 250 square centimeters (38.75 sq. in.). When one recalls that spores are either constantly or intermittently produced by a single fruit body over a long period the further statement made by Buller that "the number of spores produced by a single fungus * * * in the course of a year may, therefore, be some fifty times the population of the globe" becomes intelligible.

At least two general types of spores are recognized for most wood-destroying fungi, the most easily observed being the basidiospores produced by the fruit bodies. These may frequently be seen en masse as a white or colored powdery deposit which has fallen from the sporophores (Pl. II, fig. 4). These spores are produced on short stalks at the ends of club-shaped cells which form a palisade layer (Pl. II, fig. 6) covering the under surface of the fruit body, or, in case the fruit body is of the incrusting type, covering its outer surface. When mature, the spores are cast off the basidia into the air and are blown about by the wind. When they lodge in a moist place favorable for growth they readily germinate and produce a new infection.

[1] Bayliss, Jessie S. The biology of Polystictus versicolor (Fries). *In* Jour. Econ. Biol., v. 3, no. 1, p. 1–24, 2 pl. 1908.

[2] Buller, A. H. R. The biology of Polyporus squamosus Huds., a timber-destroying fungus. *In* Jour. Econ. Biol., v. 1, no. 3, p. 101–138, illus., pl. 5–19. 1906.

Both the fruit bodies and basidiospores vary greatly in vitality among the different species of fungi. External temperature and moisture conditions exert a great influence, particularly when the two are working together in an unfavorable rôle.

Low temperatures appear far less injurious than high temperatures. Buller and Cameron [1] report gathering living fruit bodies of *Schizophyllum commune* from a woodpile at Winnipeg, Canada, in March at a temperature of −17° C. (1° F.), after exposure for several months at winter temperatures ranging between −15° and −40° C. (5° and −40° F.). After thawing for a few hours the fruit bodies cast spores readily. They further report that immersing an active fruit body of the same fungus in water and placing it in the open over night at a minimum temperature of −31° C. (−24° F.) did not suffice to kill the organism, although it was frozen into a solid block of ice.

Carrying the work still farther, Buller [2] exposed fruit bodies of the same fungus (previously kept dry for two years and eight months in ordinary air) to the temperature of liquid air, −190° C. (−310° F.), for three weeks in a vacuum tube. Upon removal and moistening, the fruit bodies were still alive and cast spores in abundance.

In his larger work [3] and certain later articles, the same author shows that at ordinary temperatures dried fruit bodies retain their capacity to produce spores for long periods; for instance, *Daedalea unicolor* can remain alive in the dark at least 8¼ years and *Schizophyllum commune* at least 6¼ years. Certain others may retain their vitality for only two or three years.

In the case of temperatures above the optimum, however, the injurious effect may become marked within a comparatively small range. For instance, Falck [4] states that fruit bodies of *Lenzites abietina* fail to produce spores after five days at 26° (78° F.) and the spores fail to germinate at 42° C. (108° F.). A corresponding relation is also said to exist with *Merulius lachrymans* and other species, for the same author [5] states that fresh fruit bodies of *Merulius domesticus* (=*M. lachrymans* in part) are killed in 30 minutes at 40° to 42° (104° to 108° F.) and in 15 minutes at 46° C. (115° F.); at 42° C. (108° F.) dry spores are killed in 12 to 16 hours.

In addition to spores produced in fruit bodies, another set of reproductive bodies is often produced directly by the mycelium.

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[1] Buller, A. H. R., and Cameron, A. T. On the temporary suspension of vitality in the fruit bodies of certain Hymenomycetes. *In* Proc. and Trans. Roy. Soc. Canada, s. 3, v. 6, 1912, sec. 4, p. 73–78. 1913.

[2] Buller, A. H. R. Upon the retention of vitality by dried fruit bodies of certain Hymenomycetes, including an account of an experiment with liquid air. *In* Brit. Mycol. Soc. Trans., v. 4, 1912, pt. 1, p. 106–112. 1913.

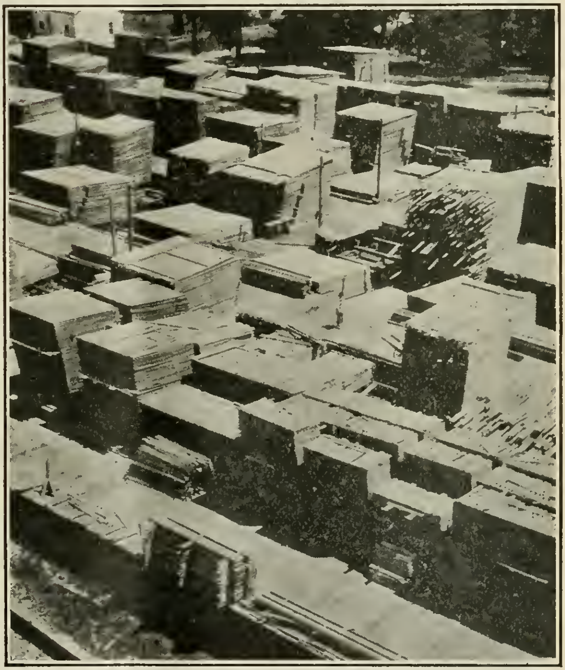
[3] Buller, A. H. R. Researches on Fungi . . . 287 p., illus., 5 fold. pl. London, 1909.

[4] Falck, Richard. Die Lenzites-Fäule des Coniferenholzes. *In* Möller, Alfred. Hausschwammforschungen. Heft 3, p. 69 and 98. 1909.

[5] Falck, Richard. Die Merulius-Fäule des Bauholzes. *In* Möller, Alfred. Hausschwammforschungen. Heft 6, p. 339. 1912.

These bodies may be borne on short stalks on the mycelial threads (conidia), or the mycelium itself may break up into short cells (oidia), or specialized thick-walled cells (chlamydospores) may form within the mycelium. The last kind of spore, on account of its thicker wall, is adapted to withstand unfavorable weather conditions; the two former kinds are usually thin walled, minute, and readily blown about by the wind.

With these fundamental facts in mind, let us now turn to a discussion of the present conditions under which timber is stored and see wherein these conditions contravene the known facts regarding the development and spread of decay-producing fungi.



P62F

FIG. 1.—Bird's-eye view of a clean lumber-mill yard in Arkansas, showing the usual method of open storage.

HANDLING TIMBER AT SAWMILLS.

The practice at different sawmills varies widely. A few of the larger mills, particularly in the longleaf-pine belt, put almost their entire cut through the dry kiln and then store it under closed sheds. This practice is to be highly commended, and if the storage sheds are well drained and properly ventilated beneath, no trouble from fungi should be experienced. However, comparatively few mills have the facilities for handling their product in this approved fashion, and the great majority have kiln capacity for only the B and better grades of lumber. The remainder of the output is piled in the open yard (fig. 1), the higher grades of lumber often being dipped in sodium bicarbonate or sodium carbonate to prevent blue stain.

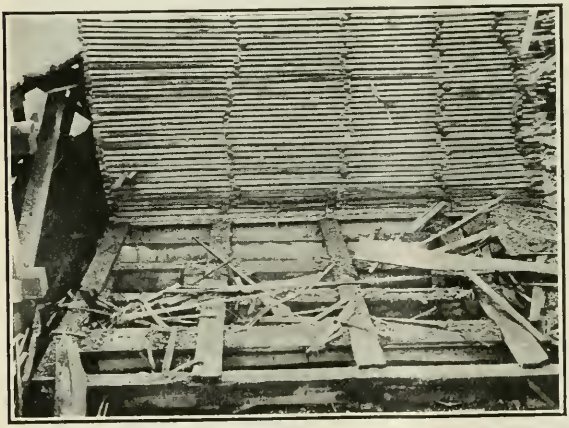
Some few mills of the poorer class and smaller type dispense with both kiln drying and dipping and pile their entire green stock in the open yard. The few mills of this type which the writer has visited are usually also very lax in their methods of piling and of yard sanitation.

LOCATION OF MILLS AND ITS RELATION TO DECAY.

The location of sawmills is usually determined by certain economic considerations which do not readily admit of change. Many of the mills are located either on streams or along the low and swampy Atlantic or Gulf coasts. Very often higher dry land is not available for storage purposes and then, particularly in the South, the conditions for decay are excellent. In some instances attempts have been made to fill in this low land with sawdust, bark débris, etc., with the result that the soil is made over into a most excellent culture medium for the development of wood-destroying fungi. In other cases yards, even when on comparatively high ground, are so graded as to allow drainage into the yard rather than away from it.

P64F

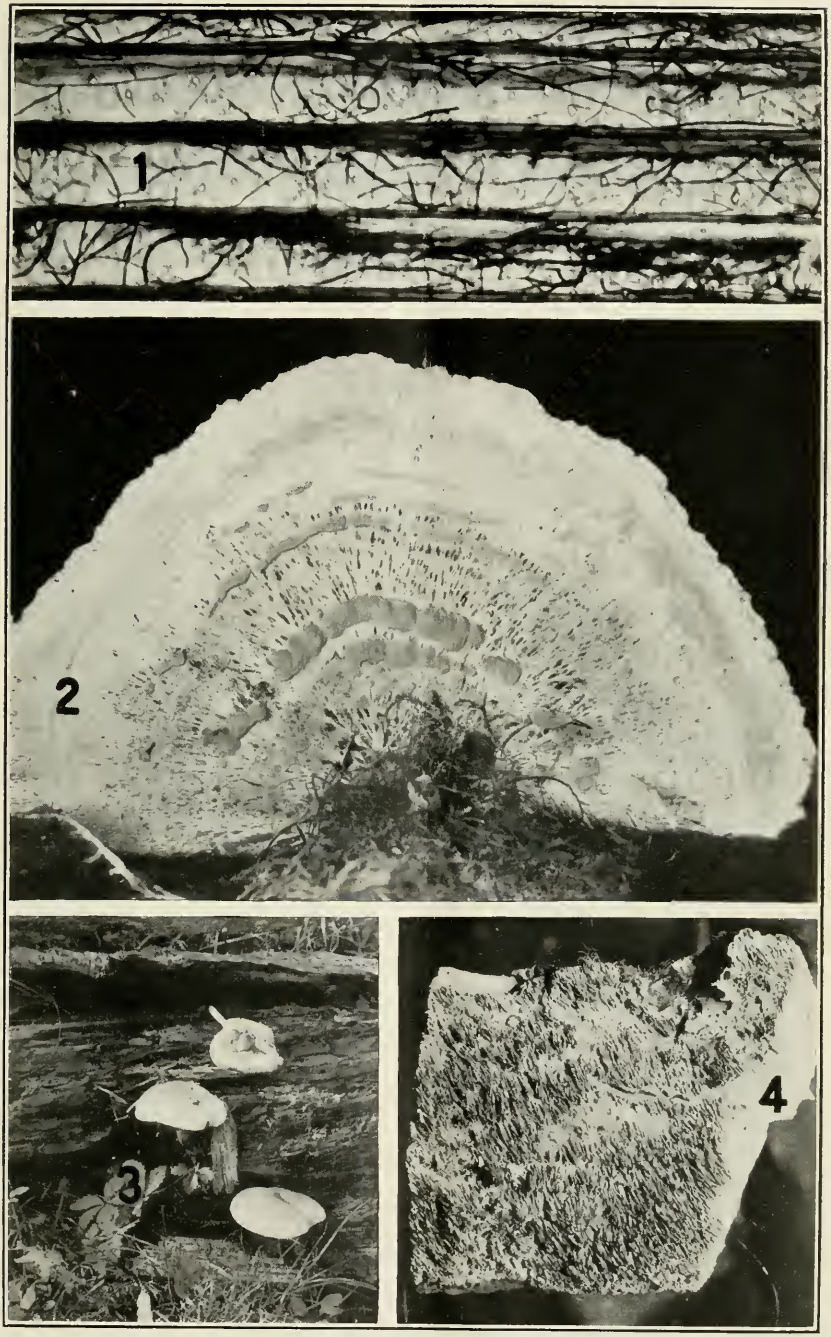
FIG. 2.—Lumber piled at the water's edge on the Atlantic coast. High waves sweep over this during storms, wetting the lumber and producing rot.



P66F

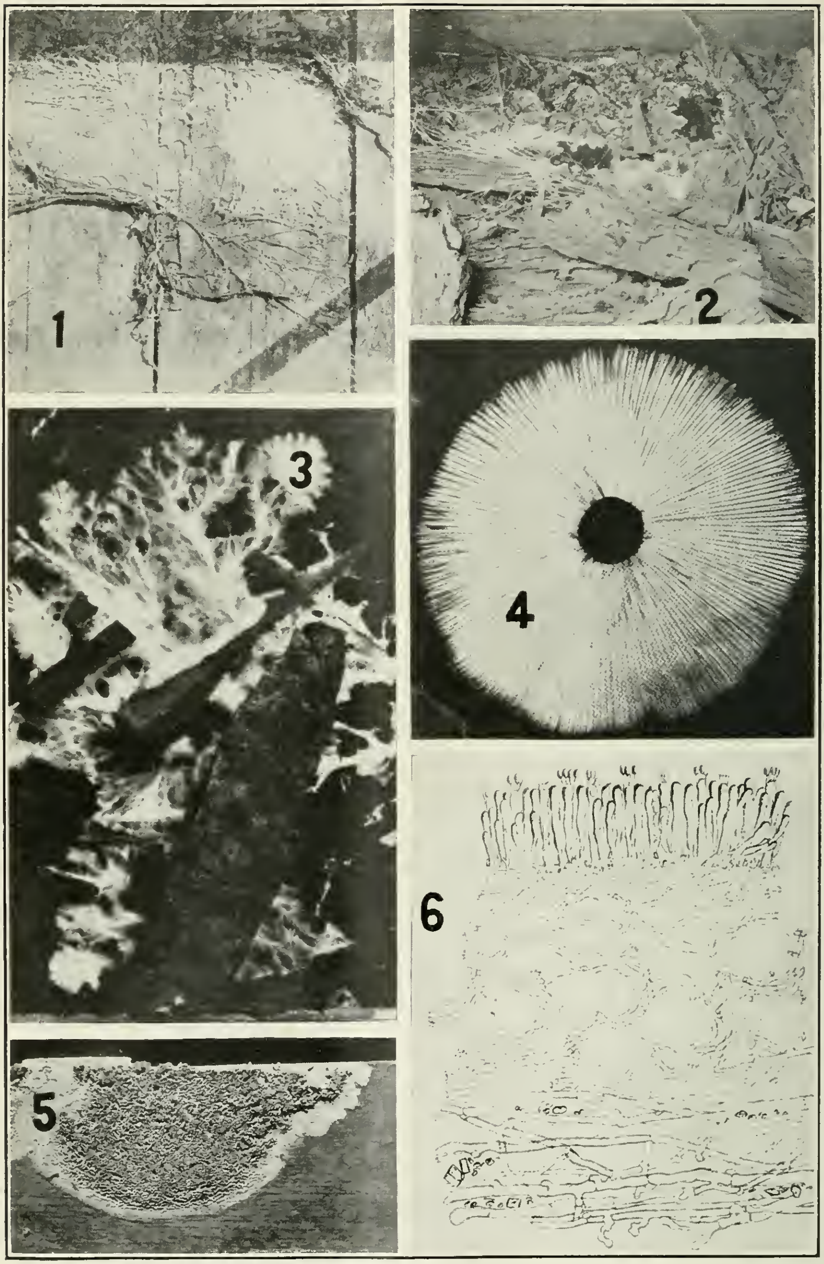
FIG. 3.—Silt deposited in the base of a lumber stack during a Mississippi River flood. This condition permits the lumber to rot rapidly.

In the coastal regions, where mills are at times located just above the level of high tide, storm waves frequently beat in from the sea



LUMBER SANITATION: WOOD-ROTTING FUNGI.—I.

FIG. 1.—Thin section of "red-heart" pine, showing fungous threads and holes where these have bored through the walls of the wood cells. FIG. 2.—Mycelium on a board from a clay mine, Joplin, Mo. FIG. 3.—The mushroom *Pluteus cervinus* on a rotten log. FIG. 4.—A species of Hydnum.



LUMBER SANITATION: WOOD-ROTTING FUNGI.—II.

FIG. 1.—Strands of mycelium of the "dry-rot" fungus, *Merulius lachrymans*, on the face of pine planks in a lumber pile at Portland, Me. (the fungus has progressed to a height of six layers or more). FIG. 2.—The same fungus on the ground and in litter beneath an open storage shed, Philadelphia, Pa. FIG. 3.—Mycelium of a white Poria on the ground and on wood fragments beneath a cotton mill, Adams, Mass. FIG. 4.—Powdery deposit of spores cast by a mushroom over night (after Atkinson). FIG. 5.—A species of Poria from a porch ceiling, Madison, Wis. FIG. 6.—Thin section of an encrusting fruit body of *Merulius lachrymans*, showing palisade layer of basidia bearing spores (after Falck).

and sweep over the lumber, wetting it and depositing silt over great quantities of the stock (fig. 2). The writer has seen instances along the Atlantic seaboard where lumber stacks at least 12 feet high were thus silted completely to the top. A somewhat similar condition exists along certain rivers during times of flood (fig. 3).

Where it is necessary to store lumber upon low swampy ground (figs. 4 and 5), the weed problem also becomes a serious factor. In the first place the growth of vegetation is so luxuriant as to require constant attention, and in the second place the ground is not even or firm enough to allow convenient mowing. The result is that sometimes the weeds are allowed to develop above the height of the foundations, thus cutting off air circulation beneath the piles and hence increasing the danger from fungi many fold.

P66F

FIG. 4.—Lumber piled on low swampy land at a Texas sawmill. The serious decay in this yard is due to the excess of soil moisture and poor circulation beneath the stacks.

QUALITY OF STOCK WITH REFERENCE TO DECAY.

The fact that American mills are utilizing their timber to a smaller size than formerly throws a greater quantity of the inferior grades upon the storage yards. Rapid deterioration in this low-grade stock may result unless it be carefully handled. In the case of many yellow-pine structural timbers it is a matter of common observation that the quality is growing decidedly poor, this being in large part due to the fact that small second-growth trees are being logged and cut into dimension sizes. In the shortleaf-pine business, in particular, a single mill rarely attempts to cut both board and dimension stock. As a rule, it is said to be more profitable to cut the better grade larger shortleaf and loblolly trees into 1 and 2 inch stock. Hence, for structural sizes the trade largely depends on certain timber mills, as well as a multitude of small portable mills operating in young second-growth timber. The storage of these less durable grades at times becomes a considerable problem, not alone at the mills but also in the retail yards. In fact, the writer has been told by certain retailers that deterioration due to decay in these low grades had become so serious with them that they had discontinued carrying such hazardous stock.

In the case of hemlock, spruces, firs, low grades of pine, and certain of the less durable hardwoods, storage difficulties are bound to develop at times during exceptionally wet seasons, but much of the trouble can be forestalled by applying the proper methods of sanitation.

P67F

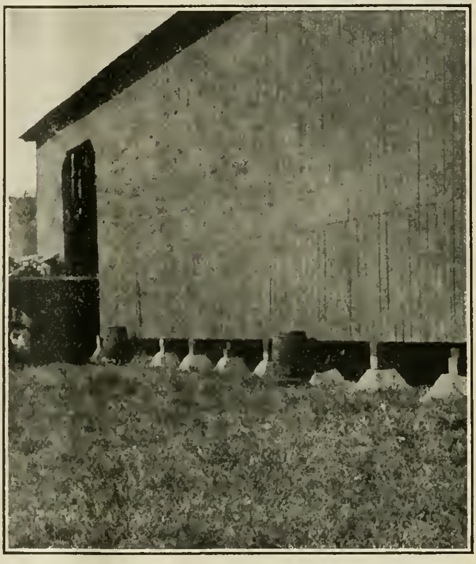
FIG. 5.—Pine lumber piled in a swamp on high skids over standing water at New Orleans, La. Note the luxuriant vegetation, which checks proper air circulation beneath the piles.

It is necessary that if such material is to enter into the construction of buildings it should be entirely free from fungous infection. Responsibility for clean lumber must rest with the lumberman.

CONDITION OF STORAGE SHEDS AT MILLS.

As noted before, many mills, including some of the larger ones, are operating under serious disadvantages of location as far as decay is concerned. The better types of storage sheds are inclosed at the sides, with ample ventilation beneath (fig. 6), but those open on both sides are not uncommonly met with. The exclusion of water from stored lumber becomes a necessity when such material is put in close piles under cover, where the drying action of wind and sun does not have full play. This is particularly true where sheds are built over low swampy ground where the vapors on rising from the wet soil are more or less imprisoned, keeping the air at a high humidity. A little extra moisture in such cases may be sufficient to permit the outbreak and rapid spread of fungous infections.

The greatest source of danger in storage sheds lies in placing the lumber too close to the ground, and several instances have been noted where widespread infections of some of the worst building fungi in the country have been prevalent in the foundation timbers and stored lumber in contact with them (Pl. X, figs. 1 and 3). Many of the sheds over low ground have drainage canals beneath to carry away excess water, and in some instances, where the pitch of the ground is not sufficient, stagnant water may accumulate over long periods. This may cause high humidities, approaching saturation, which permit the white cottony mycelium of wood-destroying fungi to develop rapidly over the surface of the timber. In general, it has been the experience of the writer that moisture conditions around the foundations of storage sheds are often very favorable to decay.



P70F

Fig. 6.—Large storage shed at Laurel, Miss., set on concrete piers, high off the ground, with ample ventilation from all sides. This is the best type of construction.

Leaky roofs at times become a source of trouble. A few instances have come to the writer's attention where comparatively small leaks have caused a considerable amount of visible, material decay in the upper parts of lumber piles. However, when we realize that in many cases the infection, on account of the short time in storage, does not have the opportunity to cause marked deterioration, but still is present in an incipient stage ready to progress farther when placed under moist conditions, we can readily see the serious consequences which may ultimately accrue.

CONDITION OF STORAGE YARDS AT MILLS.

GENERAL SANITATION.

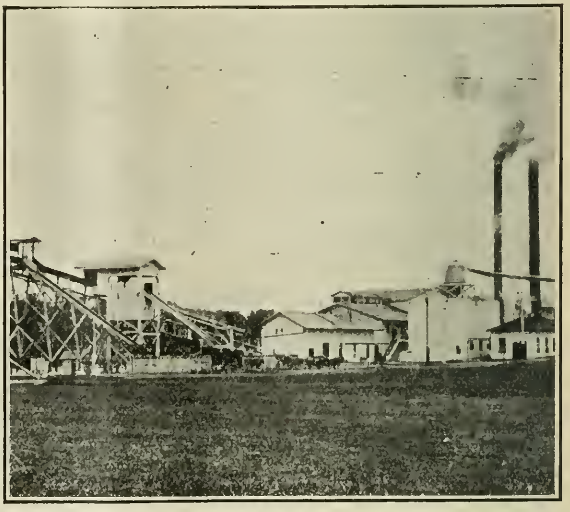
The vital necessity, viewed from the standpoint of decay, for absolute cleanliness around lumberyards is perhaps not fully appreciated by most lumbermen. The question of fire hazard, however, has led most mills to take certain steps in this direction which are of very great importance. These steps have usually assumed the form of keeping grass and weeds down, particularly in the dry season, and of removing rotten débris to a considerable extent.

A broad survey of the lumber industry shows some instances where absolutely no attention is given to yard sanitation (fig. 7) and also a few other instances where the yards are sodded and handled like a well-kept lawn (fig. 8). The great majority, however, fall between these extremes. As a rule, grass and weeds are kept under fairly good control either by mowing or by pasturing. In most instances some rotting débris is scattered about. The factor of location often plays an important part in sanitation, for on swampy land the lessened fire danger tends to encourage carelessness.

P72F

FIG. 7.—A small, very insanitary mill in Louisiana. The conditions at this mill are a disgrace to the lumber industry. Note the rotten, dilapidated tramway, the lumber stacks placed within 2 to 4 inches of the ground, and the débris scattered about and breeding infection.

Any decaying timber which has been allowed to accumulate about the yards should be collected and burned. The mere carting of such débris to a convenient near-by pile (Pl. III, fig. 1; text fig. 9) is not sufficient, for the fungi will continue to thrive in such material for long periods and to produce fruit bodies which will liberate millions upon millions of spores into



P73F

FIG. 8.—The well-kept grounds of a high-class longleaf-pine mill in Louisiana. Practically all the lumber is run through the dry kiln and stored in large sheds, thus eliminating the problem of storage rots.

the air to infect whatever sound lumber may be in the vicinity. The writer has seen scores of instances where small piles of rotting débris have been scattered about lumberyards and even at times piled directly against sound lumber (fig. 10). Very frequently this débris consists of old ties (fig. 11) or timbers from the tramway platforms. In other cases it may be yard stock which has rotted in storage and has been left in situ or carted a few rods and discarded just beyond the confines of the yard. One such mill yard was visited where several hundred thousand feet of pine and hardwood lumber had been thrown into an adjoining rice swamp in close proximity to and extending for nearly a mile along a row of lumber stacks (see fig. 9). In this same yard it was also commonly noted that sound lumber fresh from the saw was piled upon the bases of old lumber piles which were thoroughly rotted (fig. 12).

P74F

FIG. 9.—Pine and hardwood lumber which has rotted in storage in the yard shown in figure 11. Instead of burning the débris it was thrown into an adjoining rice swamp. Fungi developing on this débris will again infect the sound lumber.

Also in this yard, as well as in a yard in Mississippi, vines were allowed to grow up over some of the lumber piles (fig. 13). This is, of course, highly objectionable, since such vegetation tends to collect moisture and impedes ventilation.

Such conditions as these are bound to be a serious menace to the effective storage of lumber.

TRAMWAYS AND RAILWAYS.

Practically all sawmills have a more or less extensive tramway or railway system for the distribution of lumber from the mill to the yard and other units of the plant (fig. 14). It is quite the universal condition that these structures harbor multitudes of various wood-rotting fungi, which cast off innumerable viable spores to be carried about by air currents to sound lumber. The elevated position of these fruit bodies on high tramways gives much greater facility to the wide distribution of their spores.

Since the tramways require large amounts of timber in their construction, the use of wood preservatives in protecting them from decay is worth careful consideration. This would effect a direct saving both by prolonging the life of the timber and by preventing the development of the fungous fruit bodies.

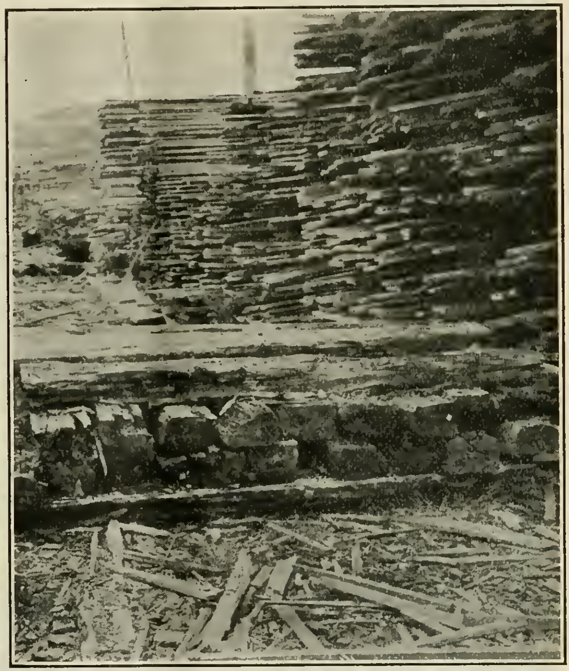
P75F

FIG. 10.—Partially rotted hardwood boards piled against a lumber stack. Infection will spread by contact to the sound lumber.

In only one part of the tramway structure is decay secondary to other deteriorating factors, and this is in the planking. Where the trucks or "buggies" operate constantly, the wear at the center very often nicely balances the decay at the ends, but even here, from the standpoint of sanitation alone, a light preservative treatment sufficient to immunize the timber so that fungous fruit bodies can not develop is strongly recommended.

The initial cost of constructing extensive tramways from 10 to 25 feet high reaches a considerable figure, even at the actual mill cost of the timber. In the upkeep of these structures replacements are necessary as rapidly as the timbers fail, the resulting maintenance charges being a considerable item of expense. In none of the mills visited had thorough wood preservative treatments been applied. Partial attempts were noted in several instances, where brush treatments, usually of some patented coal-tar compound, had been applied at the joints. Ordinarily it is the more widely advertised trade products which reach the attention of millmen. The cheaper preservatives appear to be little known. In the opinion of the writer, thorough preservative treatments would effect an ultimate saving in maintenance charges, a considerable part of the cost of application being offset by the use of cheaper grades of timber, which when treated properly will last longer than the highest grade of natural wood available.

In very few lumberyards are the railway ties preserved in any way. In most cases they consist of inferior timber which readily decays. Many fruit bodies of dangerous fungi are usually present (Pl. III, fig. 2), so that it is important from the standpoint of sanitation to remove this source of infection by the application of wood preservatives, such as creosote or zinc chlorid. A track in which the ties are creosoted is shown in figure 15.



P76F

Fig. 11.—A highly insanitary mill yard in South Carolina. Hundreds of thousands of feet of stored lumber have rotted in this yard as a result of these conditions. All this rotten débris should be removed and burned.

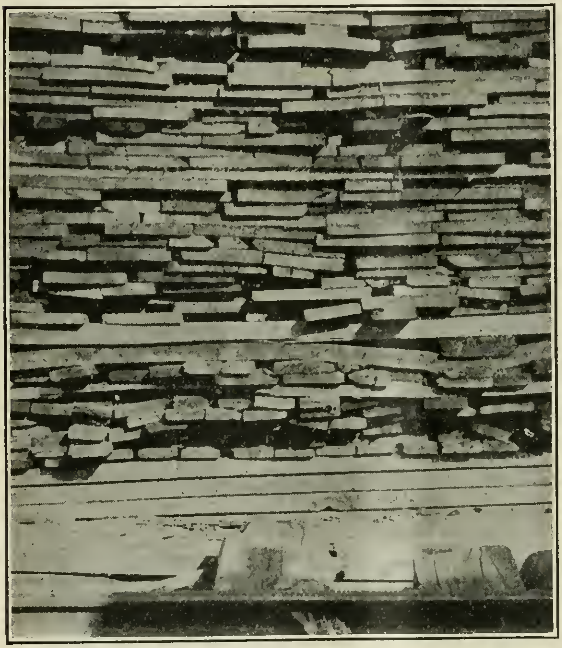
FOUNDATIONS.

Probably no other factor involved in the storage of lumber in yards is open to more criticism from the sanitation standpoint than the foundations to the piles (figs. 16 and 34). Almost invariably these timbers are severely infected and often abundantly supplied with sporulating fruit bodies of serious wood-rotting fungi (Pl. III, figs. 3 and 4).

Various types of foundations are in use. The most primitive and most insanitary type consists in laying planks directly on the ground and stacking the lumber upon them. This procedure occurs at only a few of the smaller mills. A few of the mills make use of built-up plank foundations (Pl. III, fig. 3), but the more usual method is to use 6 by 8 or 8 by 10 stringers, blocked up to a height of

1 to 2 feet (fig. 16) or set on short posts. A few of the best mills make use of concrete piers for this purpose. The latter type of foundation would be greatly improved by the use of stringers treated with a wood preservative.

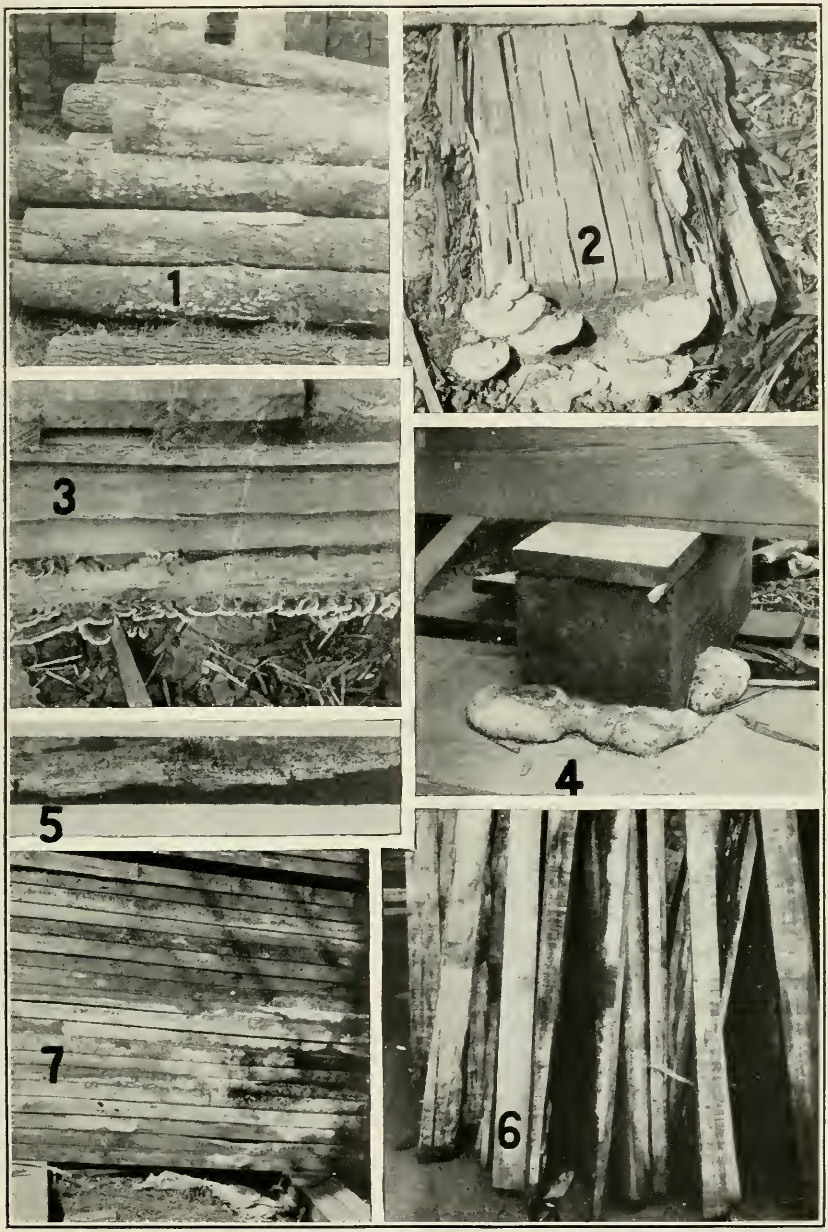
The dangers arising from partially rotted foundations are evident, as has been seen from the earlier discussion of the activities of wood-destroying fungi. Where wood blocks are used to support the skids, fungi often progress directly from the moist soil upward, in this way frequently infecting the skids, thus adding the possibility of direct mycelial infection to that of spore infection. The infected skids themselves are dangerous, since the fungous mycelium can progress directly from them to the bottom of the lumber piles (Pl. IV, fig. 3; text fig. 17). Once started, and the weather conditions being warm and moist, such infections may pass through an entire stack. In considering the menace of infected skids, we must also not lose sight of the fact that such timbers are a prolific source of fruit bodies (Pl. III, fig. 3) with their many spores, to be borne up into the lumber piles either directly by the wind or by convection currents which occur in relatively still air. The proof of this latter form of air currents is often before us in the form of rising mists or fogs.



P77F

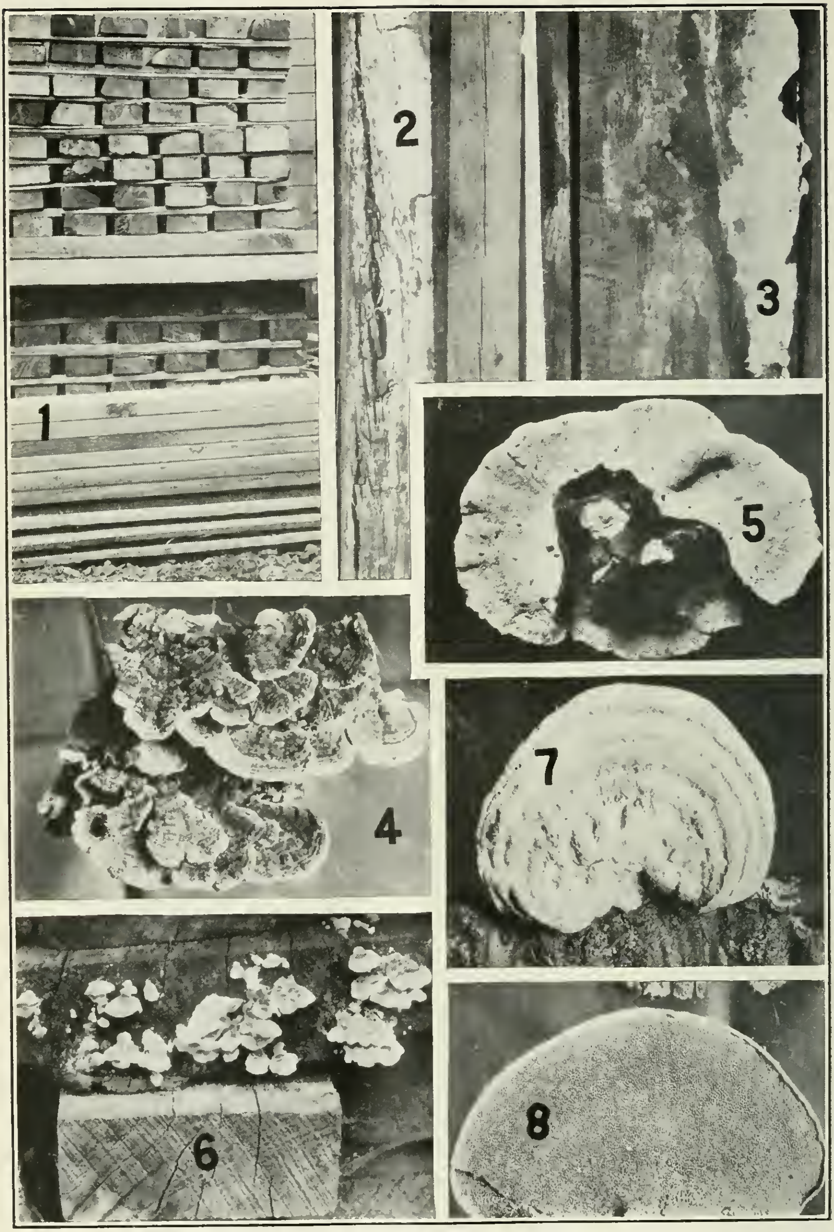
FIG. 12.—Rotten base of an old hardwood stack upon which sound lumber has been piled. This is a most insanitary practice, as fungous infection will be spread both by the contact of the diseased with the sound lumber and indirectly by the production of fruit bodies and spores, the latter blowing about, reaching sound material, and germinating to produce new infections.

The first requisite in building foundations is to get them well off the ground, so as to allow ample ventilation beneath, which will dry out the timbers themselves as well as the soil below. A height of at least 24 inches from the top of the skids to the surface of the ground should be adhered to.



LUMBER SANITATION: WOOD-ROTTING FUNGI.—III.

FIG. 1.—A pile of rejected hardwood logs which should have been removed or destroyed and not left to breed fungi (fruit bodies of 6 or 7 different organisms were identified from this pile). FIG. 2.—*Lenzites berkeleyi* fruiting on a hardwood tie. FIG. 3.—Hardwood pile foundations severely infected with *Polystictus versicolor*. FIG. 4.—*Daedalea quercina* fruiting around a foundation block in a Pennsylvania storage yard. FIG. 5.—A badly infected piling stick in use at a Florida mill. FIG. 6.—A group of infected piling sticks at a Tennessee hardwood mill. FIG. 7.—Pile of 3-inch hard pine planks badly infected with *Peniophora gigantea* (a very common condition at Portland, Me.; the fungus is introduced from the South and develops rapidly in close piles).

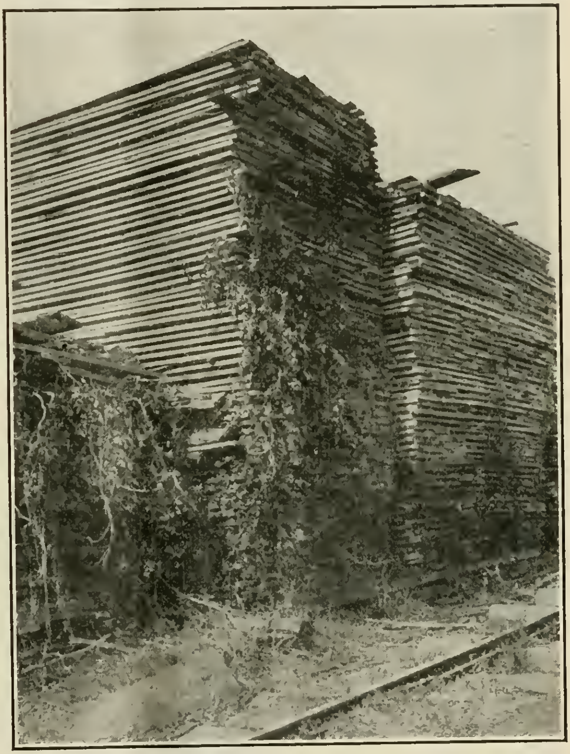


LUMBER SANITATION: WOOD-ROTTING FUNGI.—IV.

FIG. 1.—Shortleaf pine which has rotted during 10 months' storage in a retail yard at New Orleans. FIG. 2.—A structural pine timber which lay on the ground until severely rotted and was then thrown up into a pile of sound lumber. FIG. 3.—Mycelium of a wood-destroying fungus on the face of pine boards just uncovered in breaking down a pile (at a height of 6 to 8 boards from the bottom, but probably has gone much higher). FIGS. 4 to 6.—*Polystictus versicolor:* 4, Upper surface; 5, lower surface; 6, plant growing on the end of a hardwood board in a lumber pile. FIGS. 7 and 8.—*Polystictus hirsutus:* 7, Upper surface; 8, lower surface.

The use of untreated wood blocking, particularly on low, moist ground, should be discouraged, as such material invariably harbors fungi.

The most desirable practice, and one which would be free from all objections, is the use of concrete or brick piers, preferably the former, and skid timbers treated with some preservative. Such skids, about 24 inches high, treated with creosote, are now in use at the Forest Products Laboratory (fig. 18).

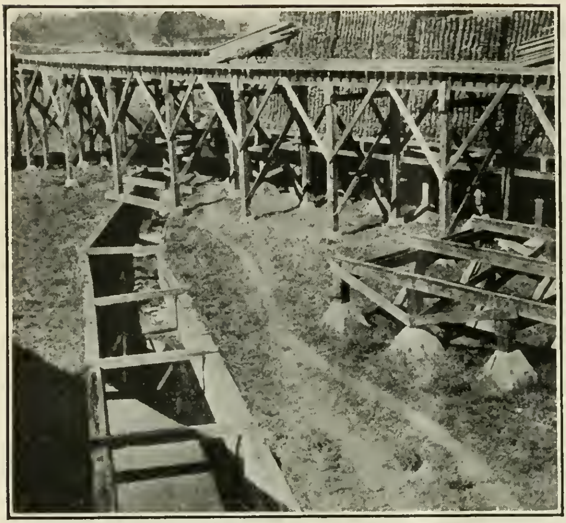


P78F

FIG. 13.—Vines growing over lumber piles. From a pathological standpoint this condition should be condemned, because the dense foliage prevents the lumber from rapidly drying out after rains, thus promoting decay.

Foundations with concrete piers and untreated skids are at present in use in a number of yards and have given entire satisfaction. At one Mississippi mill (figs. 14 and 19) unfavorable conditions of low ground have been mainly overcome by good drainage, careful attention to the removal of débris, and the use of concrete foundations well off the ground. A description of the foundations and their cost may be of interest.

The foundations were placed and the tramways rebuilt between 1908 and 1910, after a number of years of unsatisfactory experience with wood, at a reported cost of about $30,000 for a mill having an annual cut around 60,000,000 feet of pine a year. In the two years preceding the placing of the concrete foundations and the rebuilding of the tramways, the annual charge for material and labor in the upkeep of the yard was $18,000 and $17,000, respectively. Following the equipment of the yard with concrete foundation piers and concrete footings for the tramway posts, this charge was materially reduced. The present maintenance cost as reported by the company,



P79F

FIG 14.—General view of a mill yard in Mississippi, showing concrete pile foundations and tramway footings. The ditch assists materially in draining the yard. No débris is allowed to accumulate. The stacks are high off the ground and amply ventilated beneath. The tramway and pile foundation timbers would be improved by a preservative treatment with creosote.

based on a consumption of 600,000 feet of timber a year at a value of $12 per 1,000 feet b. m., is $7,200, or 12 cents per thousand of mill cut. The timber used consists of pine heart seconds having an average life of 5 to 6 years and a maximum life of 8 to 10 years for material not in contact with the ground; pile foundations and tramway footings average 4 to 5 years.

In addition to the direct saving in maintenance charges, we must also keep in mind the advantage gained in preventing deterioration in the stored lumber itself, due to improved sanitation. While this item is very difficult to estimate, the company believes it a very appreciable asset of its storage practice.

The approved type of concrete foundation pier now in use by this company is of the form illustrated in figure 20, consisting of a base block 3 feet square, tapering upward and cast in position. Upon this base block is cast the top block, 2 feet square and also taper-

P135F

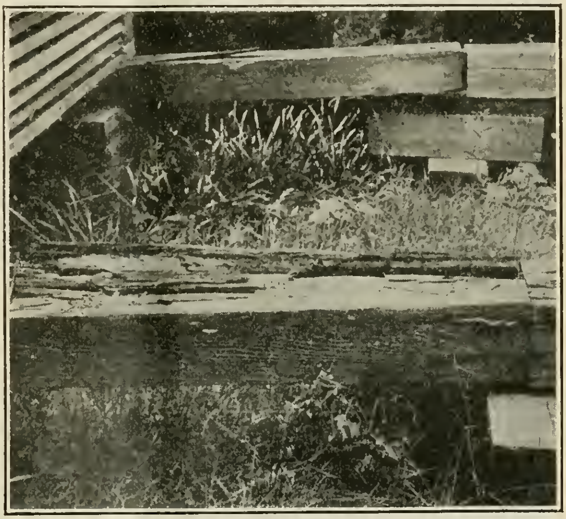
FIG. 15.—A clean, sanitary retail yard, having concrete foundations throughout and creosoted ties in the railroad track.

ing upward, being 1 foot square at the top, which gives a good bearing surface for the horizontal wooden skids or for the vertical posts where it is necessary to elevate the skids to a height consistent with the height of the tramways.

A concrete mixture of 1–2½–5 is used, at a cost for labor and material of $5 per cubic yard, or an average cost of about $5 per pier.

The foundations follow the slightly varying contour of the ground. To compensate for the more marked differences in soil elevation the skid timbers are frequently blocked up to an approximately level condition by the use of short sections of pine posts treated at the ends with a tar or cresote preparation.

There are two advantages in casting the piers in two pieces: (1) The reduction in weight of the individual blocks when it becomes necessary to shift them about the yard, and (2) the greater ease of alignment when erecting the skids.



P80F

FIG. 16.—Thoroughly rotted pine skids in a mill yard in Texas. Such decayed foundation timbers are very common. Fungous infection can pass directly from these timbers to the lumber piled on them. Creosote would have prevented this condition.

All the skids are well off the ground at heights never less than 18 to 24 inches and frequently 36 inches and over. The lumber is not piled directly on the wooden skid timbers, but rests on a 1-inch pine strip, usually about 3 inches wide, to give a smaller bearing surface. This method is not uncommonly employed in various yards. It is of distinct advantage where lumber is piled on infected skids, and if the dry strips are freshly laid for each pile they materially assist in reducing infections in the base of the stack.

In direct contrast to these concrete foundations with ample ventilation beneath, one frequently meets with the type illustrated in figure 21. The one figured is built of 2-inch pecky cypress planks about 14 feet long, resting directly on the ground. The amount of lumber used was computed for one of the squares and totaled approximately 585 feet b. m. While pecky cypress is often used in the South for foundations of this type, in many other cases either nondurable hardwoods or the cheaper grades of pine are used. Decay is often serious in such foundations. There is very little chance for ventilation, and this often leads to storage rots in the base of the piles.

The open type of foundation is always much the better from a pathological standpoint. In certain of the Gulf cities, where municipalities in cooperation with the United States Public Health Service are making strong efforts to get rid of rats to safeguard against the bubonic plague, certain ordinances have been passed requiring structures to be raised at least 12 inches from the ground and left open beneath. This requirement will react very favorably upon lumber storage, for the first necessity is to get the timber off the ground, with ample ventilation beneath. Figure 22 illustrates the method of elevating the skids employed in a retail lumberyard at Mobile, Ala., which has only recently occupied the premises.

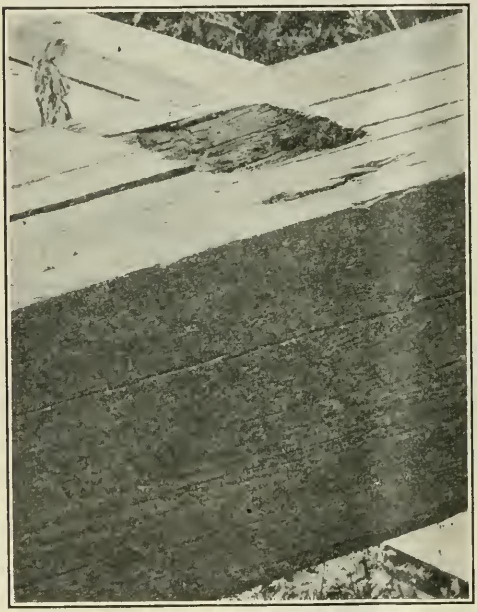


FIG. 17.—A 12 by 12 inch hard-pine timber, showing a rotten hole in the face which lay in contact with infected skids.

Timber foundations are frequently the cause of considerable trouble on account of decay failure under heavy loads, thus allowing the piles to topple over or to crush to the ground, where they have every opportunity to rot. Figure 23 shows two such piles at a South Carolina mill. Rot in foundation timbers is extremely common and, in fact, has been encountered in practically every yard examined where timbers are employed for this purpose.

PILING STICKS.

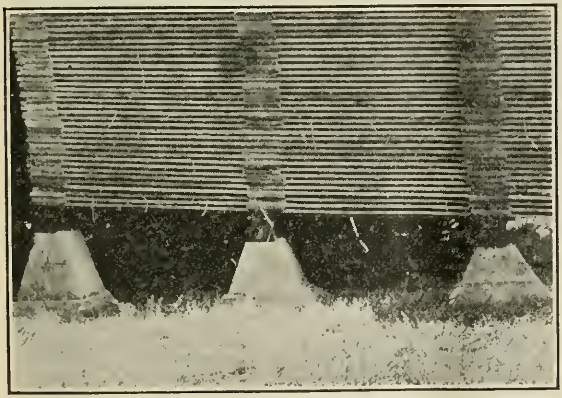
Practically all yards in which the lumber is "stuck" fail to appreciate the necessity of keeping the sticks free from infection. The strong tendency is to scatter them about on the ground wherever they happened to fall when the previous piles were taken down (fig. 24). In a very few yards attempts are made to improve the appearance of the premises by gathering the sticks endwise into conical piles or by stacking them carefully on the ground beneath the skids (fig. 25).

This question of the sanitary handling of the piling sticks is of very great significance, particularly in regions of high humidity, where every precaution must be taken to safeguard stored lumber. Plate III, figures 5 and 6, shows such infected sticks found in Florida and Tennessee lumberyards, where several species of wood-destroying fungi were frequently noted in the piles.

P82F

FIG. 18.—Pile foundations consisting of creosoted timbers resting on concrete piers in use at the Forest Products Laboratory, Madison, Wis. This is a very satisfactory type of foundation.

When one keeps in mind the fact that the soil in and about lumberyards often becomes, in the course of time, thoroughly intermixed with sawdust and partially decomposed woody matter which offers a fertile field for the development of wood-destroying fungi, the necessity of keeping all sound material out of contact with it becomes very evident. In cases where sawdust and bark or wood débris are used to produce artificial fills the danger is further increased. Such filling materials are not infrequently used.



P83F

FIG. 19.—Concrete foundations with untreated skid timbers in general use in a mill yard at Laurel, Miss. Only two rows of piers are used for stock 14 feet or less in length.

Such situations introduce the further question as to what material should be used for filling in low portions of the yards. While the material used will necessarily be governed largely by local conditions, it is the opinion of the writer that clean clay or sandy soil will serve the purpose admirably. While sandy soil allows fungi to spread within it more rapidly than clay, it offers the advantage of rapid seepage, and where the surface is amply ventilated no difficulty should be experienced. (Pl. X, figs 1 and 3.)

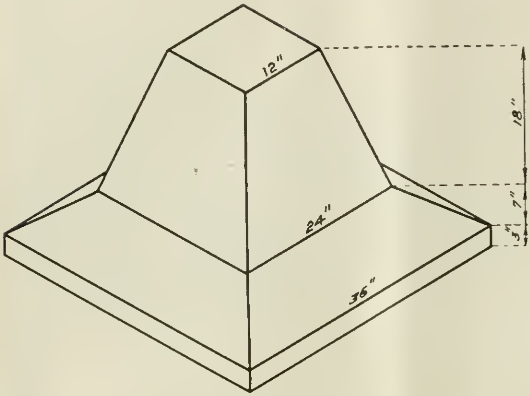
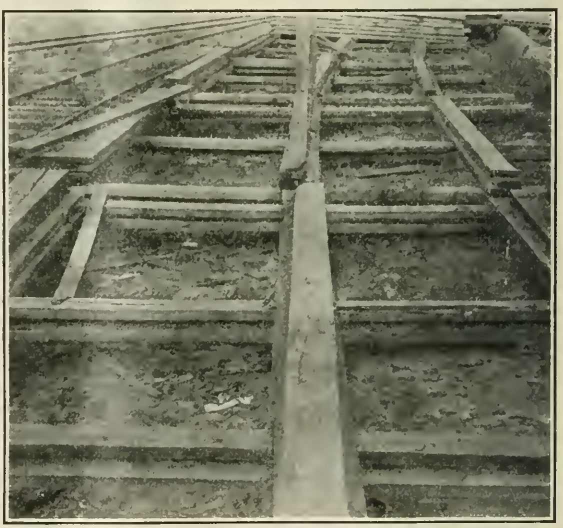


FIG. 20.—Sketch of a concrete foundation pier in use in a mill yard in Mississippi. It is cast in two sections, for convenience in aligning and moving about the yard.

The principal need is to have the yards so laid out that surface water will not accumulate. Ordinary ashes are not considsidered a good filling or surfacing material, since they absorb moisture readily and hold it tenaciously, particularly when they are in a finely pulverized condition. Less finely divided material, such as coarse cinders, gravel, or slag, is better adapted on account of the rapid seepage. Moreover, wood-destroying fungi appear to grow through ashes quite readily when they are in a moist condition. In fact, the writer has a record of one case where fungi developed luxuriantly in a pile of ashes in the open when exposed to prolonged rainy weather. (Pl. IX, fig. 3.)

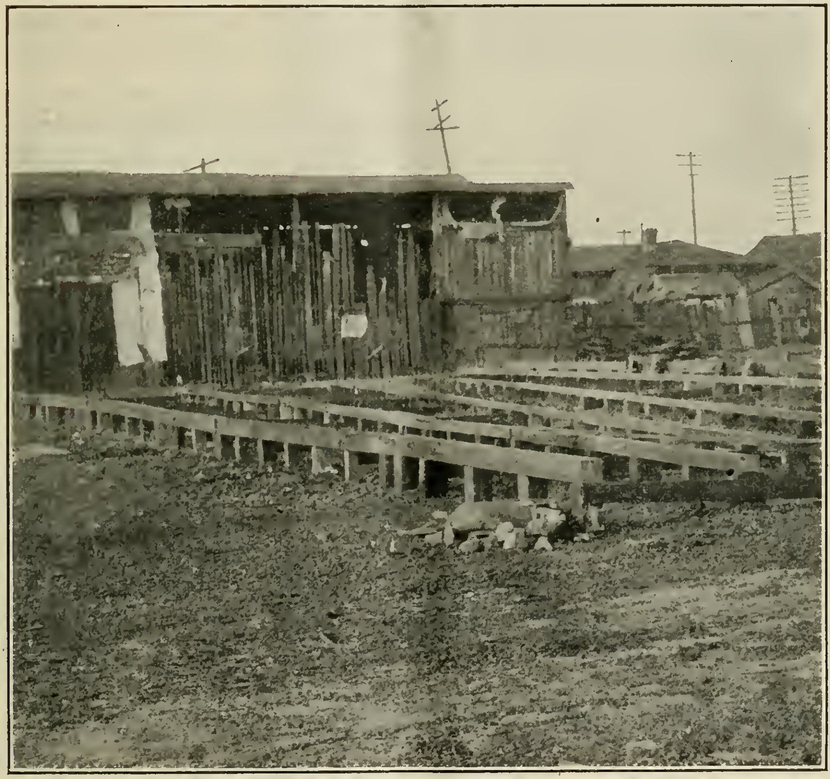


P84F

FIG. 21.—Pecky cypress foundations in use at a mill in South Carolina. Each large square contains from 500 to 600 board feet. This type of construction does not allow sufficient ventilation beneath the piles.

METHODS OF STACKING LUMBER.

Lumber piled in the open must be allowed ventilation around the individual pieces, and this is usually arranged for in storage practice. In some instances, however, this necessity is ignored in certain retail yards where it is the custom to dispose of the stock within very short periods, say, two or three months. In some of the northern retail yards along the Atlantic coast, where southern pine comes in by boat in a comparatively green condition, this practice often leads to severe fungous infections throughout entire piles. This infection undoubtedly gets a good start in the hold of the vessel during transit and propagates further when close piled in congested lumberyards. Such a pile of diseased pine is



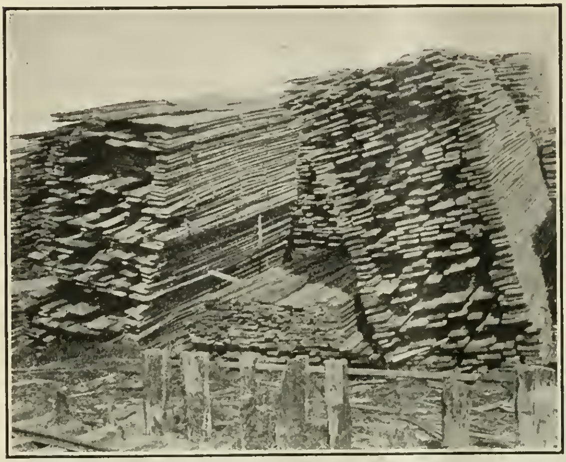
P85F

Fig. 22.—Foundations at Mobile, Ala., built to conform to an ordinance requiring all structures to be raised at least 12 inches off the ground and left open underneath.

shown in Plate III, figure 7, where the infection extends up high into the stack.

It is not the intention in the present bulletin to enter into a discussion of detailed methods of stacking lumber. The primary concern, from the standpoint of sanitation, is to dry the lumber as rapidly as possible and maintain it in this condition. However, other considerations, such as checking and warping, must be taken into account in many instances. The humidity or dryness of the climate will be of great weight in determining the proper amount of ventilation to give the best results from all standpoints.

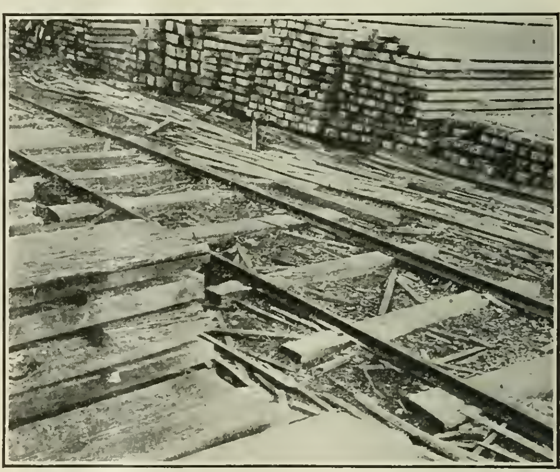
Certain general considerations, however, apply to practically all cases. The method of using special narrow cross sticks is probably in greatest use, and this offers certain advantages when the sticks are handled in a sanitary manner. In the first place, the strips are kept in an air-dry condition, which offers considerable advantage over green material; in the second place, the strips, being narrow, do not offer a bearing surface more than 1 to 4 inches wide. A distinct advantage would also accrue with the use of sticks cut from highly durable material; for instance, resinous heart pine or resistant hardwoods, such as white oak and heart red gum.



P86F

FIG. 23.—Foundations which have failed through decay, permitting the piles to topple over. This would have been prevented by the use of a good preservative.

The second general method of piling lumber consists in using the narrower widths of the lumber itself for crossing strips (fig. 26). The wider boards ordinarily offer too much of a bearing surface for good air circulation. At one of the Arkansas mills visited it was customary in the earlier days to use the regular run of lumber up to 12 inches wide as crossers, but this practice was discontinued on account of the serious loss from decay. The manager of the mill informed the writer that considerable rot would occur in 8 to 12 inch stock



P87F

FIG. 24.—Piling sticks lying on the ground at a mill in South Carolina, showing the insanitary method of handling them. Such sticks lying for only a week or two in contact with fungus-infected ground may themselves become seriously infected, and decay may in turn pass on to the lumber stacks.

within a year under such conditions. The present practice is to use strips 4 inches wide and 1 inch thick of air-dry No. 2 pine. This method has proved entirely satisfactory.

In laying sticks careful attention should be paid to placing the successive strips vertically one above the other. If they are placed hit or miss, certain ones may fall in the span of the next tier below, thus producing much unnecessary warping of the lumber, due to the pressure of the overlying layers.

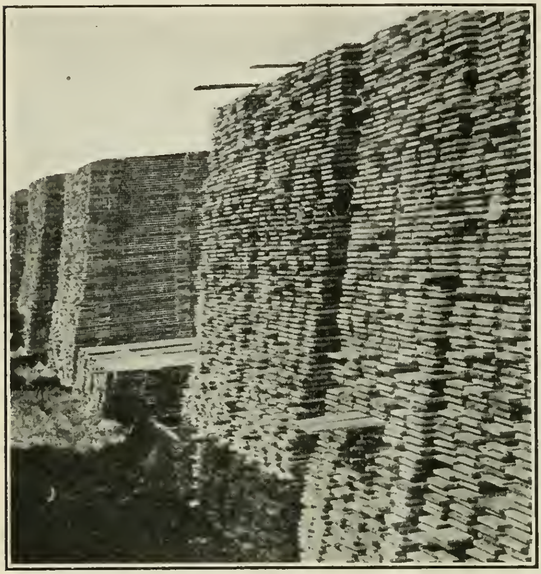
In all cases of flat piling of green lumber care should be taken to leave a space of at least half an inch between the edges of the stock. This gives a vertical air circulation, which is particularly effective.

P88F

FIG. 25.—Piling sticks placed on wet ground beneath the skids. In order to keep them free from infection, such sticks should never be placed in contact with the soil.

Two other methods of piling 2 to 3 inch stock are used to some extent with good results. The edge piling of 2 by 4's (fig. 27), sticking the pieces in the usual way, has given good results at several mills where flat piling produced an appreciable amount of deterioration. The method of flat piling without the use of sticks, occasionally employed with 2 by 6's, in which horizontal circulation is provided for by leaving wide spaces between the edges of the stock (fig. 28), would not appear to offer as good opportunities for drying lumber in a moist climate as the more usual method which makes use of sticks.

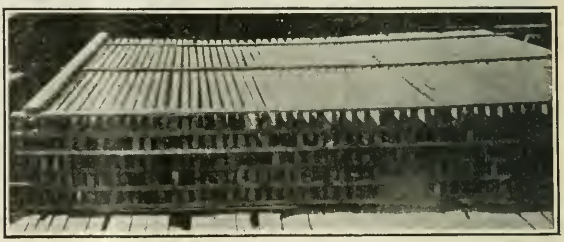
Besides the proper sticking and lateral spacing of lumber, a central flue one board wide running vertically through the middle of the pile is often of decided advantage. Many millmen recognize this as good practice, but few of them consider they have sufficient yard space to carry out the method consistently.



P89F

FIG. 26.—Lumber piled in even lengths in a southern mill yard. The crossing strips consist of the narrower widths of lumber.

Another factor which enters into the storage of lumber is the piling of stock in even or approximately uniform lengths (see fig. 26). A few mills consider that such preliminary sorting is feasible from an economic standpoint, on account of the greater facility with which such stock can be billed out. From a pathological standpoint the practice is highly commendable. Uneven lengths allow rains to beat in, and also offer convenient and favorable lodging places for fungous spores. Likewise, marked disparities in length permit considerable warping of the ends, which often project out several feet from the main body of the pile. Figure 29 shows this condition in an exaggerated form. To protect the ends of the lumber from beating rains as far as possible, the cross strips should be placed at least flush with the ends, both in front and behind.



P90F

FIG. 27.—Edge-piled 2 by 4 pine at an Arkansas mill. This method of piling permits better vertical air circulation and consequently more rapid drying and less danger from decay during storage.

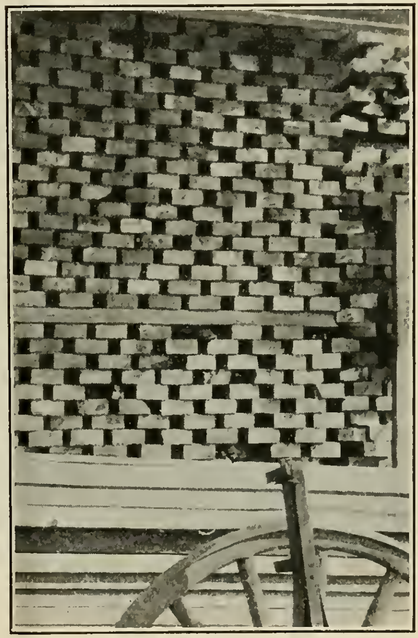
There still remains the question of roofing the piles. The commonly accepted pitch for lumber piles is 1 inch to the foot, and with a loose roof of lapped boards the greater part of the rainfall will drain away. The roofs must necessarily extend somewhat beyond the piles, in order to carry the drip clear of the stack at the rear. Roofing the piles should never be omitted, as the protection afforded against rain is of undoubted value and the operation itself adds very little to the cost of piling.

HANDLING TIMBER AT RETAIL YARDS.

The storage problems involved at retail yards are somewhat different from those at mills, although they may be discussed under exactly similar heads.

LOCATION OF YARDS WITH REFERENCE TO DECAY.

As a first observation, we may say in general that retail or wholesale yards, as opposed to yards in connection with a sawmill, have the advantage of a higher and drier location, which, in turn, should make sanitation measures easier to practice. The necessity of locating on streams or bodies of water is not ordinarily a prime consideration, but rather the location on or near a railway line and as convenient as possible to the actual consumer. Naturally, in the seaport towns, where much of the lumber comes in by boat, the most favorable location from the standpoint of transportation is along the water front, but in inland towns, where the shipment of lumber is by rail, the other factors of accessibility to the local market and the price of land play the important part.



P91F

FIG. 28. — Two-inch stock piled without sticks, a method rarely used in the yards visited. Not used, as far as observed, with stock less than 6 inches wide.

This general advantage of location, however, is often considerably offset by the necessity for close piling, without adequate ventilation either between the piles or through them, due to the higher cost of land. When this is coupled with the fact that much of the product has been in storage elsewhere for varying periods, sometimes a year or more, it can readily be seen why decay is rather frequently encountered in the retail yard.

The salvation of the retail dealers usually lies in disposing of their stock rapidly. Most of them aim to turn it at least three or four times a year, for they recognize that long storage will prove disastrous. Timber showing deterioration through decay is not difficult to find in most retail yards. However, this is very often only in the incipient stage and is not readily noticed by the casual observer. Yards which dress the lumber just before filling orders can in this way supply to the trade clean-looking lumber, but this does not always imply freedom from fungous infection. The opinion seems to be prevalent among many lumber dealers that the mere brightening of the lumber by running through the planer serves to remove all objection to infected stock. This is far from the fact, however. It merely gives it a better sale appearance, and the danger to the ultimate user still remains. The adage that "beauty is only skin deep" applies to such infected stock with particular force.

While perhaps the majority of lumber dealers have merely overlooked the full significance to the building trades of the dangers which lurk in diseased stock and are trying in every way to satisfy their trade and meet competition, there still remain a considerable number who do not look into the future but are content to get the stock off their own hands without any care as to the service which it will give the consumer. This is a thoroughly mistaken policy, for the lumberman should in every way strive to increase the value of his product. In the first place, it is good business policy, and, second, there remains the question of moral and legal responsibility.

P92F

FIG. 29.—A stack of pine lumber of uneven lengths. Note the irregular distribution of the piling sticks and the consequent warping and twisting of the boards.

STORAGE SHEDS.

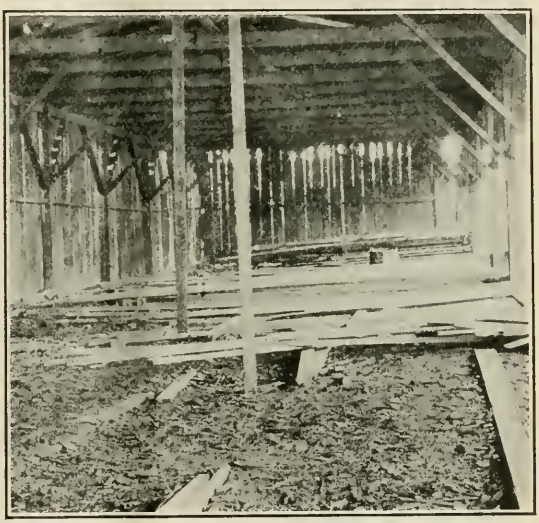
In many retail yards shed conditions are very poor. The closed type of shed is in the minority. Since lumber under cover is as a rule piled closely in bins, the need for ample ventilation beneath and a tight roof above is imperative. All the decay observed in lumber sheds is directly traceable to one or the other of these factors; mainly, however, that of improper ventilation. It has frequently been the custom merely to lay a narrow timber sill directly on the ground, or at best within a very few inches of it, to serve for the foundation (fig. 30). The best practice, however, has been to place the sills on brick or concrete piers not less than 18 to 24 inches high, running the siding of the shed only to the bottom of the sills, so as to allow a free circulation of air regardless of the direction of the wind. Such a construction is represented in figure 31.

Another defect of the open shed which has been frequently noted is the strong tendency to allow the ends of the longer stock to project beyond the eaves (fig. 32). Very few sheds are equipped with gutters (fig. 31), and the drip during rains may run back along the projecting pieces well into the center of the piles. When once wetted the close piles will retain this moisture for long periods, during which a serious outbreak of decay may be initiated.

A few cases of severe outbreaks in retail lumber sheds will be described and illustrated later.

YARDS.

On account of very limited storage space, nearly all retail yards fail to observe the proper spacing of lumber to insure ample ventilation. The general tendency is to pile altogether too close to the ground for safety, and in many instances the lumber is not spaced as well in the piles as it should be (fig. 33). The principal danger lies in the foundations, which are very often seriously infected with rot (fig. 34) or are not adequately constructed to insure proper ventilation. The danger in allowing lumber to come in contact with the soil is evident in figure 35. As the question of foundations in mill yards was discussed in considerable detail earlier in this publication and since the fundamental considerations apply with equal force to retail yards, only certain features which serve to connect these fundamentals with the direct problems of the retail yard will be added here.



P93F

FIG. 30.—An old, dilapidated shed on the Mobile River in which the lumber is too close to the ground. Many severe cases of rot have developed under just such conditions.

Many retail lumber yards use solid or latticed foundations of built-up plank running parallel to the alleys (figs. 36 and 37): others resort to wood blocking for the support of the skids. The use of concrete is very limited, but has given complete satisfaction wherever introduced. It is usually laid down as solid foundations parallel to the alleys. In one yard at Birmingham, Ala., the foundations were 8 to 10 inches high, 6 inches thick at the top, and placed in triple parallel rows spaced 7 feet apart (fig. 38). The advantage of reinforcing the concrete is well shown in figure 39.

Somewhat higher foundations than these are to be preferred in many situations, but in this yard, where every precaution was taken to keep the ground free from all infected débris, and where the drainage was excellent, this height has proved satisfactory.

Piers have the advantage over a solid wall in permitting better ventilation, but piers also involve the use of wooden skids, which if not treated with a good preservative may more than offset the advantage gained in better ventilation.

The careless handling of crossing sticks and lumber in retail yards is just as evident as in mill yards. The general practice in many of the yards visited is to throw sticks about on the ground when the stacks are torn down, and there they often remain until they are needed again. This insanitary practice needs no further comment. A comparison of the yard shown in figure 40, where the lumber is scattered about promiscuously on the ground, with the yard shown in figure 15, where concrete foundations and treated ties are in use and all débris is carefully collected into a wagon (fig. 41) and hauled away, may be of interest in this connection.

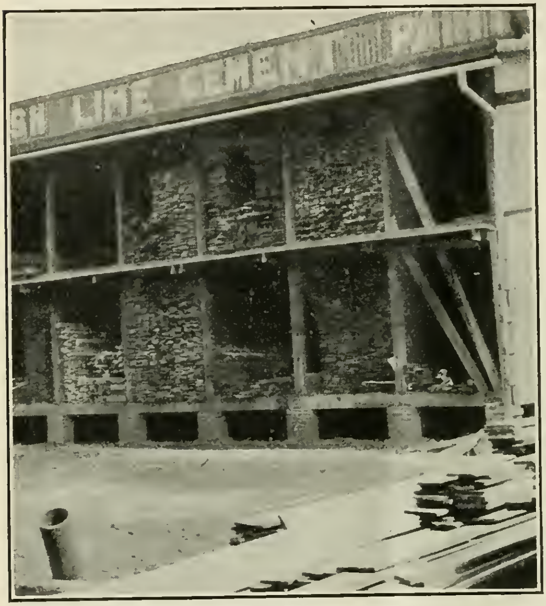

P95F

FIG. 31.—A retail shed in Tennessee, well roofed, provided with gutters, and set on brick piers with ample ventilation beneath from all sides.

FUNGI WHICH ROT STORED LUMBER.

A considerable number of different species of wood-destroying fungi have been encountered in lumberyards. These, of course, are more frequently found fruiting on the foundations, tramway timbers, and ties than on the stored lumber, but this is only a question of the time which the timbers have been in the yard. The fact that elevated tramway posts and girders will rot in the South in a few years is proof conclusive that lumber stored in the open will also rot if it becomes necessary to hold it in storage too long. In the Gulf States low-grade lumber stored in the ordinary manner will show considerable deterioration within a year. Plate IV, figure 1, shows a small pile of shortleaf pine seriously rotted after a period of only 10 months in a retail yard at New Orleans; in fact, the owner of this yard suffered so much loss from decay in the less durable grades of pine that he has discontinued handling them.

Fungi are in evidence in lumberyards in the vegetative stage (moldlike growths; Pl. II, fig. 1, and Pl. IV, figs. 2 and 3) and in the fruiting stage. Almost any species occurring in a given region may occasionally be introduced into storage yards, but the great majority of the specimens found fruiting fall within a comparatively few species.

P94F

Fig. 32.—A retail shed in Alabama in which the lumber projects beyond the eaves, thus catching the drip from rains. This condition favors decay when the water runs back along the boards into the piles.

One of the common forms, *Polystictus versicolor* (L.) Fr., is shown in Plate IV, figures 4, 5, and 6, growing both from the ends of stored hardwood lumber and from built-up plank foundations (Pl. III, fig. 3). This organism is profusely distributed throughout the entire United States and is more destructive to hardwood timber than any other fungus.

Other members of this genus, such as *Polystictus hirsutus* (Schräd.) Fr. (Pl. IV, figs. 7 and 8), *P. pargamenus* Fr. (Pl. V, figs. 1 and 2), and *P. abietinus* Fr. (Pl. V, figs. 3 and 4) are likely to be found in most lumberyards throughout the United States, occasionally fruiting on stored lumber, but more often causing sap rots of tramway timbers, foundations; and ties. The last species grows on coniferous timber almost exclusively; the other two on hardwood timber.

Among other members of the true pore fungi may be mentioned *Polyporus adustus* (Willd.) Fr. (Pl. V, figs. 5 and 6), which is usually thin, tough, and leathery, creamy above and smoky below; *P. sanguineus* (L.) Fr. (Pl. VI, fig. 4), of a bright red throughout, shiny above, rather thin and shelflike, which is found abundantly throughout the South on hardwood timbers; and *P. gilvus* Schw. (Pl. VI, figs. 2 and 3), a firm, comparatively thin, rather rigid species, yellowish within and reddish brown without as it ages.

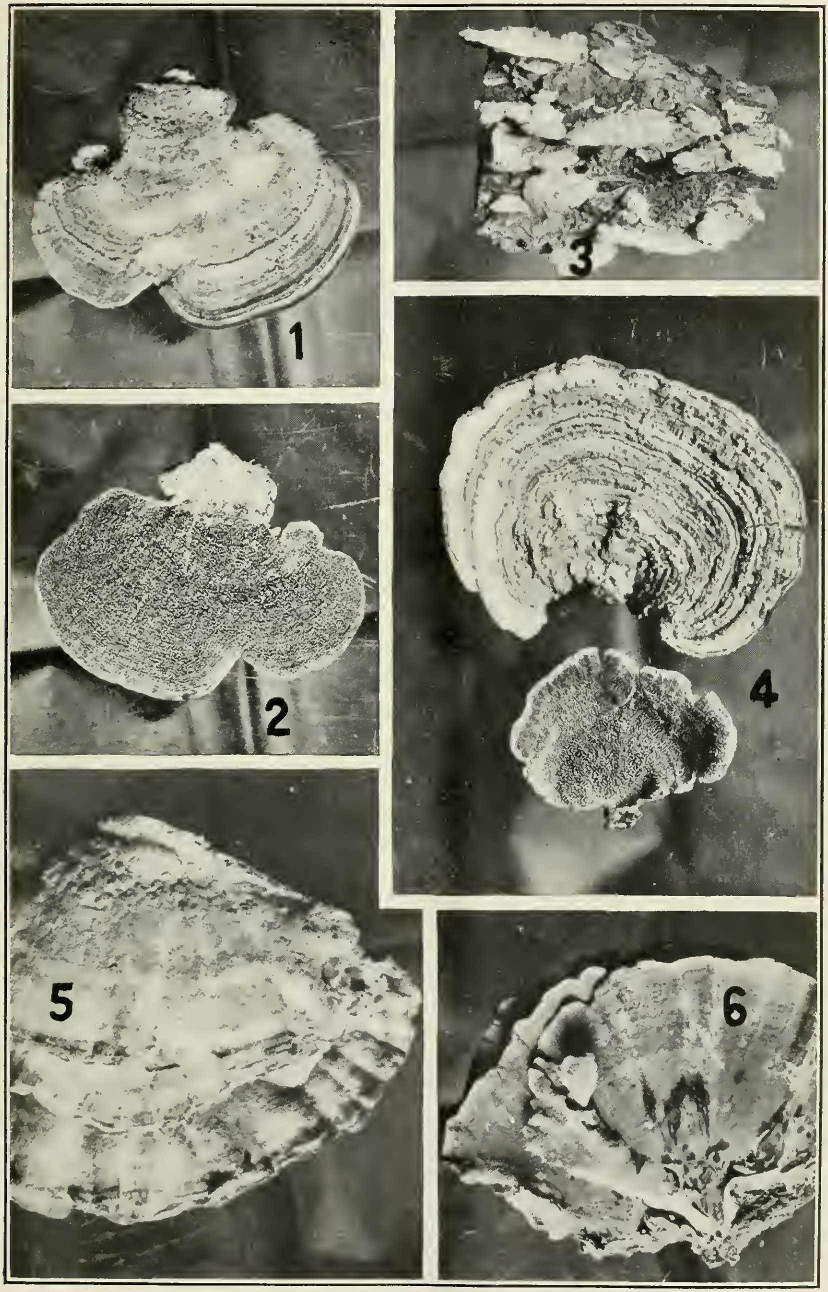
In the northeastern United States one occasionally finds on oak or chestnut timbers the heavy, tough, corky fruit bodies of *Daedalea quercina* (L.) Pers. (Pl. VI, fig. 1). When the plant develops normally it forms large and sinuous pores, but in lumberyards it more often appears as abortive clay-colored cushions (Pl. III, fig. 4). It is one of the few fungi which attack white oak and chestnut.

Another destructive group of fungi is represented by the genus Lenzites. Among the brown species there are three principal ones to be feared: *Lenzites sepiaria* (Wulf.) Fr. (Pl. VI, figs. 5 and 6), *L. berkeleyi* Sacc. (Pl. VI, fig. 7), and *L. trabea* (Pers.) Fr. (Pl. VII, fig. 1). The first two constitute the most serious enemies of coniferous structural timber in the United States. The last species rots both the heartwood and sapwood of many different kinds of hardwoods. All three are brown throughout and leathery to corky in texture. In some fruit bodies the under surface may consist of distinct gills; in others, the gills may more or less run together to form sinuous to subcircular pores, easily visible to the naked eye.

P96F

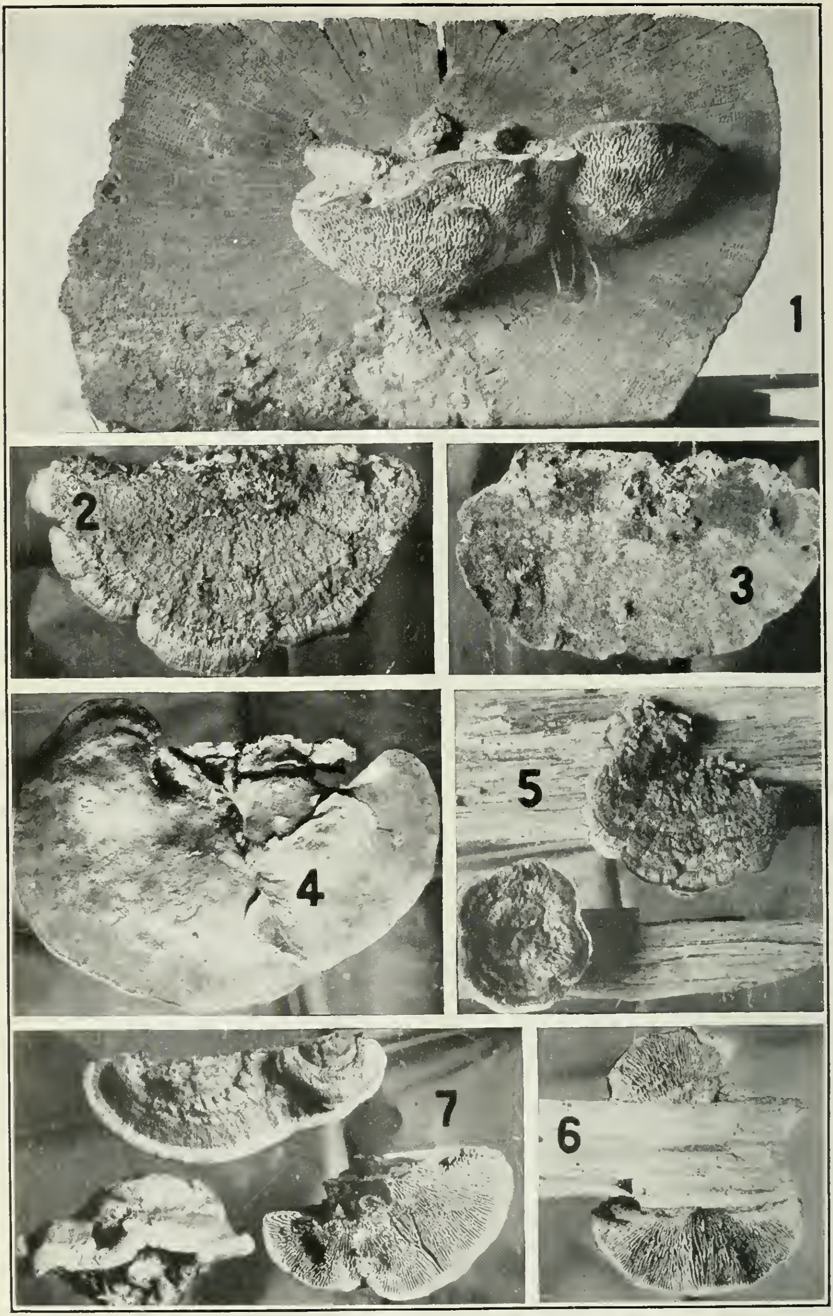
Fig. 33.—A very congested retail yard at New Orleans, La., showing lumber temporarily placed on the ground in solid piles. This is a bad practice, because under such conditions decay may start in a very short time.

Another species, *Lenzites betulina* (L.) Fr. (Pl. VII, figs. 2 and 3), of a general creamy color, with an upper surface frequently banded with shades of yellow, orange, and brown, occurs on hardwood timber throughout the United States. It has commonly been noted in lumberyards on timbers used in various structures. In one large mill yard where oak was largely used for planking the elevated tramways, this species, in conjunction with *Polystictus versicolor*, suc-



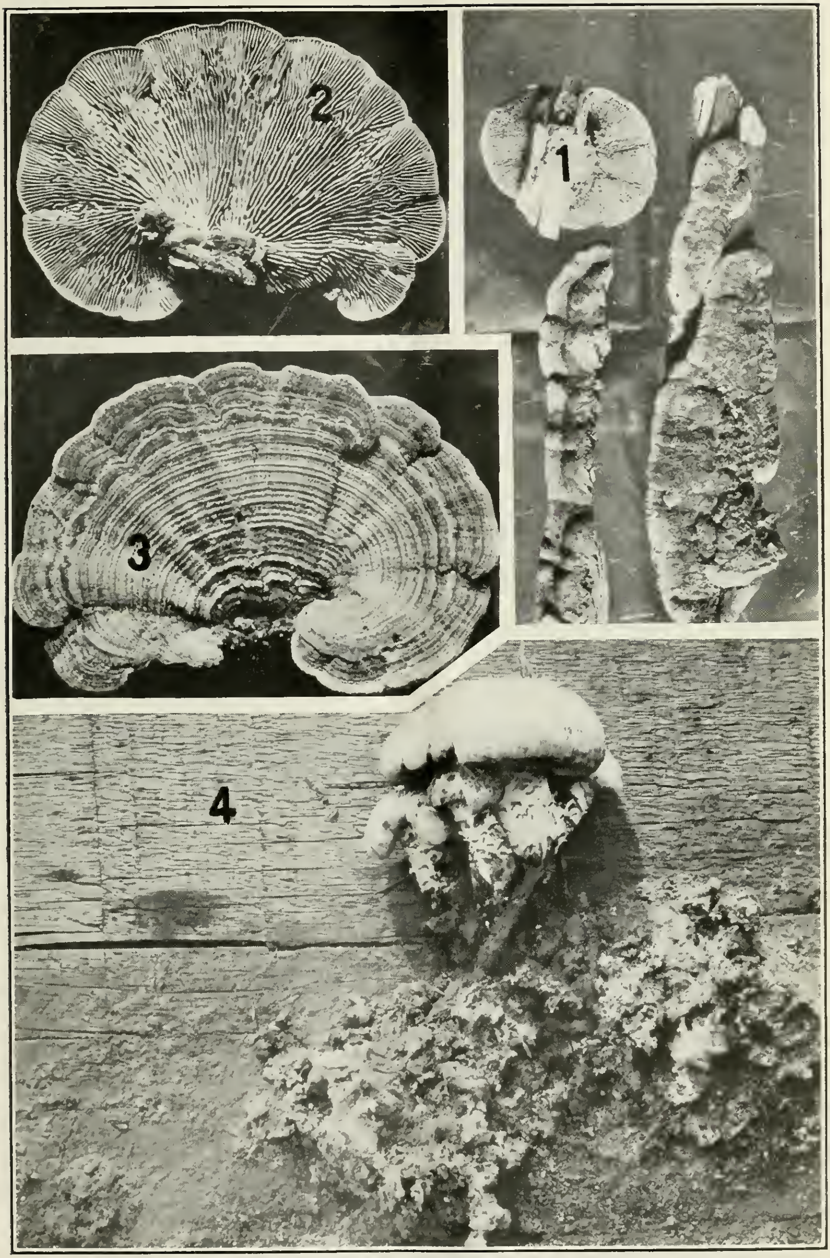
LUMBER SANITATION: WOOD-ROTTING FUNGI.—V.

FIGS. 1 and 2.—*Polystictus pargamenus:* 1, Upper surface; 2, lower surface. FIGS. 3 and 4.—*Polystictus abietinus:* 3, Typical form from a pine log; 4, plants showing upper and lower surfaces. FIGS. 5 and 6.—*Polyporus adustus:* 5, Upper surface; 6, lower surface.



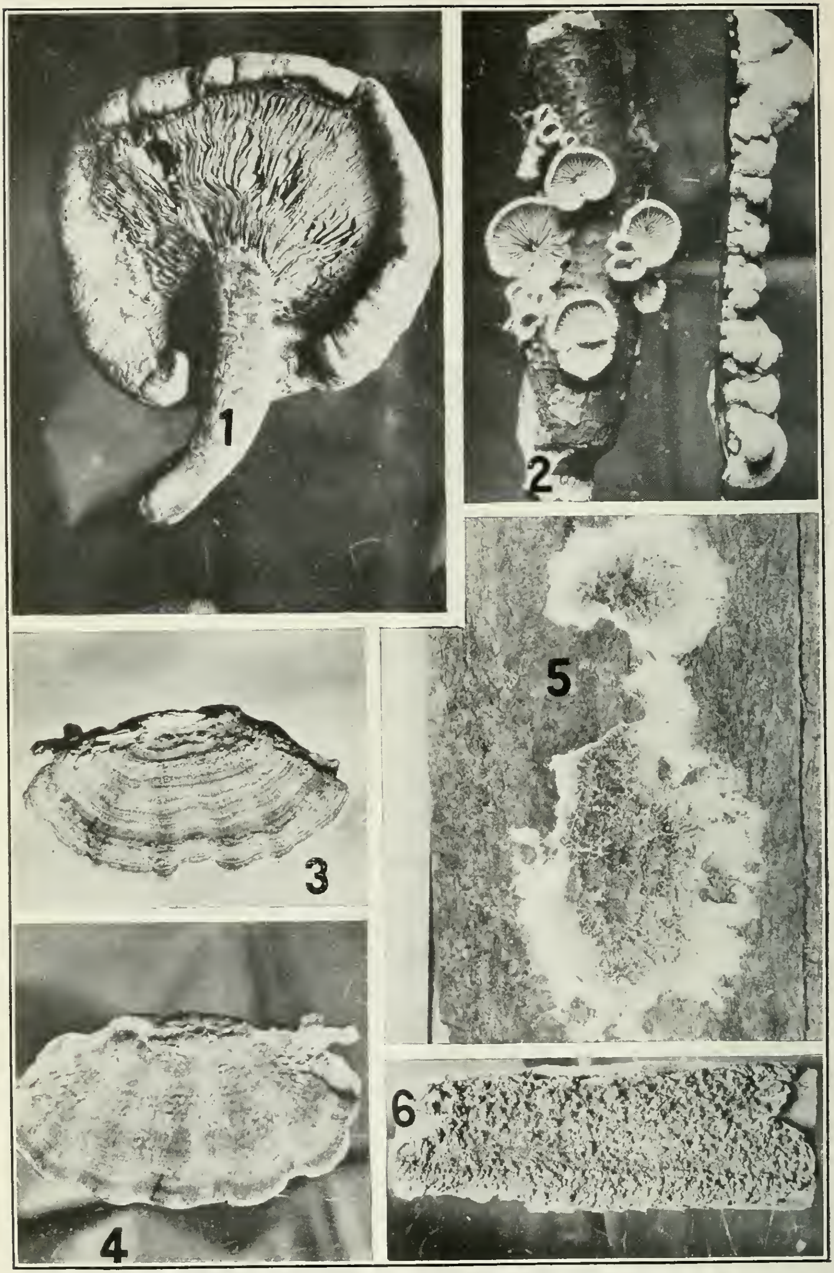
LUMBER SANITATION: WOOD-ROTTING FUNGI.—VI.

FIG. 1.—*Daedalea quercina* growing on an oak tie. FIGS. 2 and 3.—*Polyporus gilvus:* 2, Upper surface; 3, lower surface. FIG. 4.—*Polyporus sanguineus*, upper surface. FIGS. 5 and 6.—*Lenzites sepiaria:* 5, Upper surface; 6, lower surface. FIG. 7.—*Lenzites berkeleyi*, upper and lower surfaces.



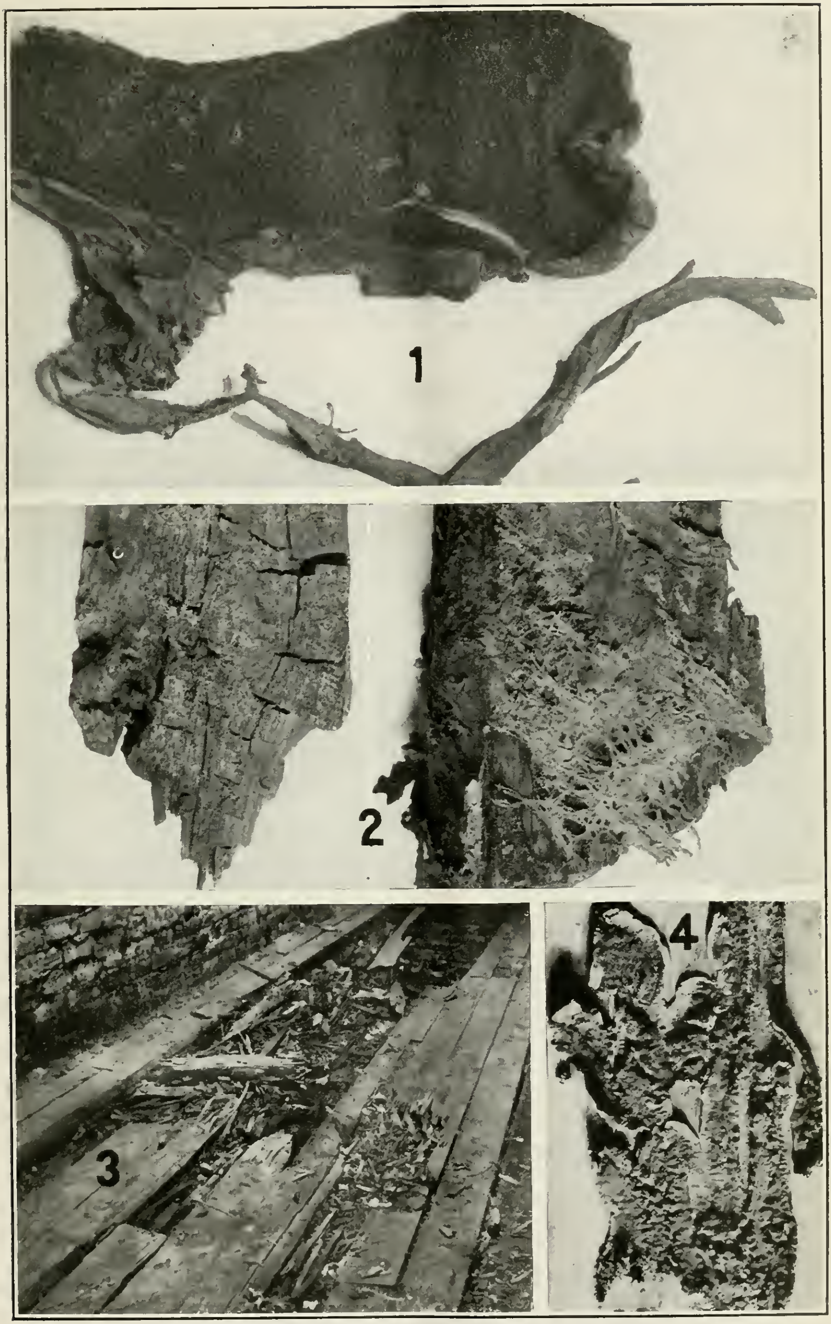
LUMBER SANITATION: WOOD-ROTTING FUNGI.—VII.

FIG. 1.—*Lenzites trabea*, upper and lower surfaces. FIGS. 2 and 3.—*Lenzites betulina:* 2, Lower surface; 3, upper surface. FIG. 4.—*Lentinus lepideus*, typical form on railway ties.



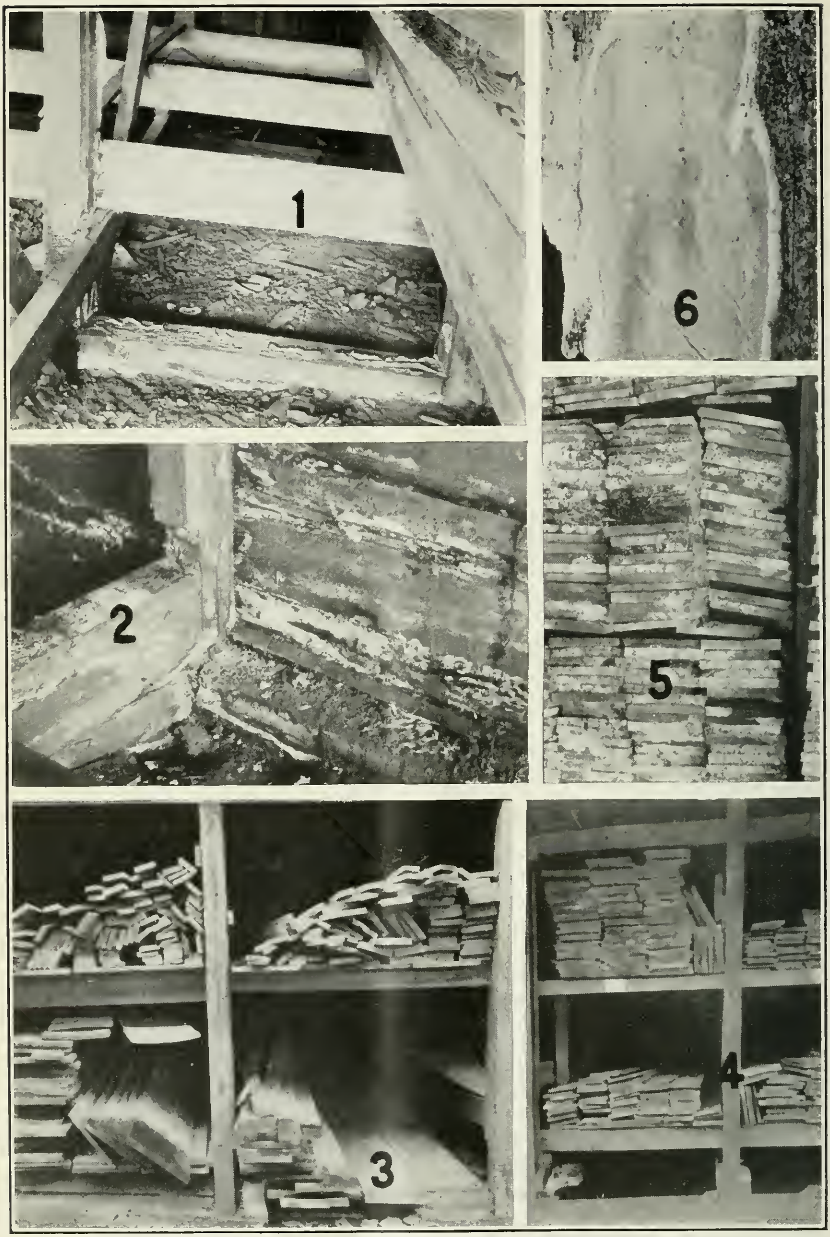
LUMBER SANITATION: WOOD-ROTTING FUNGI.—VIII.

FIG. 1.—*Lentinus lepideus*, under surface. FIG. 2.—*Schizophyllum commune*, upper and lower surfaces. FIGS. 3 and 4.—*Stereum fasciatum:* 3, Upper surface; 4, lower surface. FIGS. 5 and 6.—*Coniophora puteana:* 5, Smooth form growing on spruce sheeting in a mine; 6, warted form from a mine.



LUMBER SANITATION: WOOD-ROTTING FUNGI.—IX.

FIGS. 1 and 2.—*Merulius lachrymans:* 1, A well-developed fruit body with porous moisture-conducting strand (from a residence in Pennsylvania); 2, mycelium growing over the surface of the rotten wood. FIGS. 3 and 4.—An unidentified fungus in a Mississippi cotton warehouse; 3, flooring rotted by the organism; 4, fruit bodies developing on other parts of the floor. (This is the same species illustrated in Plate X, figures 1 and 2.)

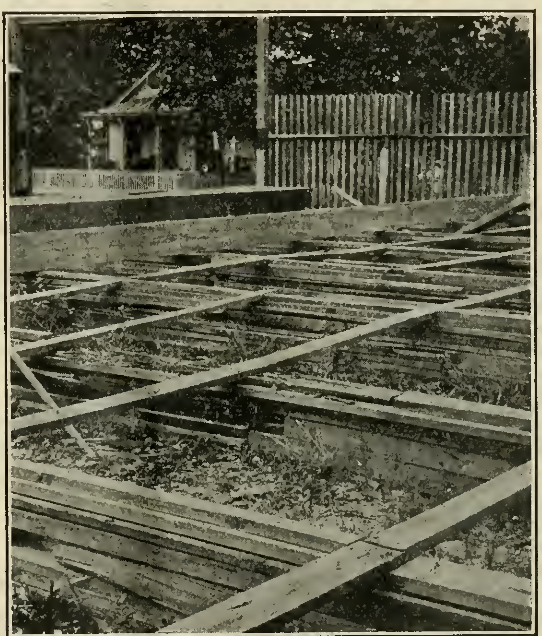


LUMBER SANITATION: WOOD-ROTTING FUNGI.—X.

FIGS. 1 to 4.—A severe infection of an unidentified fungus in an Alabama lumber yard: 1, Open shed where the fungus has progressed upward to the second bin, 5 feet from the ground; 2, corner of closed shed on the same premises where rolls of tarred roofing paper resting on the floor (not shown in the picture) were severely rotted at the ends; 3, the shed shown in figure 1, showing how the infection started by piling too close to the ground over a cinder fill; 4, the same shed after the lower bins had been raised in an effort to control the spread of the rot. FIGS. 5 and 6.—*Peniophora gigantea:* 5, Intermixed with molds and developing on moist pine shingles in a close pile in a Tennessee retail yard (growth, which an antiseptic dip at the mill would have prevented, had started during transit); 6, the mature stage growing on a pine log.

ceeded in rotting the planks at practically the same rate at which they wore down mechanically.

Of the true gill fungi may be mentioned two species—*Schizophyllum commune* Fr. (Pl. VIII, fig. 2) and *Lentinus lepideus* Fr. (Pl. VII, fig. 4, and Pl. VIII, fig. 1). The former occurs everywhere in the United States on both coniferous and hardwood timber. It is white to grayish, very thin and flexible, woolly above, and has very distinct gills below, which are split longitudinally at the edge and each half curled over, much as a dandelion stem curls when split. It is a comparatively small fungus, usually not projecting out more than 1 or 1½ inches. At times it is attached at the center of the back and then presents a circular outline with the gills radiating from a common center. When dry it is much curled and inrolled, but during rainy weather it readily revives and appears fresh and expanded again. Fortunately, it deteriorates wood but slightly and need occasion no fear among lumber users.



P97F

FIG. 34.—Built-up pine foundations in a retail yard in Tennessee. Many of the foundation timbers are seriously decayed and infection may pass to timbers piled in contact with them. Figure 17 shows what happened to a structural timber placed on a foundation in this yard similar to these.

Lentinus lepideus Fr. is a fungus of the "toadstool" type, with a circular, broadly convex, scaly cap, and a stout, fibrous, central or eccentric stem. It is white throughout, except for the brownish scales on the upper side of the caps and on the stem. The under side is provided with coarse gills, which become considerably toothed and split as the plant ages.

This fungus is a very rapid grower and primarily attacks timber in contact with the soil. It rots pine railway ties very rapidly, growing through sandy soil from one stick to another. Serious outbreaks of the fungus in pine warehouse floors have been reported several times, and it should be carefully guarded against in lumber storage yards.

Of the fungi having a smooth under surface, two species are common enemies of structural timber—*Stereum fasciatum* Schw. (Pl. VIII, figs. 3 and 4) and *S. lobatum* Knze. These fungi are too much alike for the layman to attempt to distinguish between them. They are very thin and flexible, the individual shelves often growing one above the other. The general color is grayish to creamy.

Among the incrusting forms three deserve particular attention, viz, *Merulius lachrymans* (Wulf.) Fr., *Coniophora puteana* (Schum.) Fr. (=*C. cerebella* (Pers.) Schröt.), and *Peniophora gigantea* (Fr.) Mass. The first two species are notoriously dangerous and have been found in a number of lumberyards extending from Massachusetts to the Gulf of Mexico. They are also the most frequently reported of all fungi occurring in buildings, and also the most destructive.

P98F

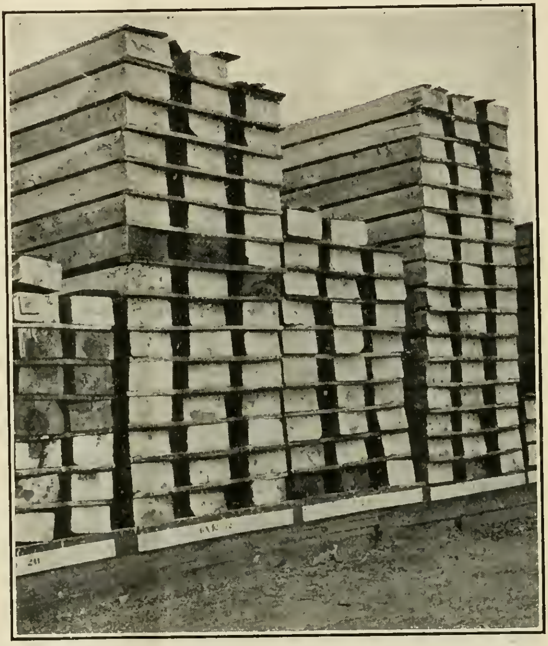
FIG. 35.—Projecting ends of lumber which have decayed by coming in contact with the ground.

Merulius lachrymans (Pl. II, figs. 1, 2, and 6, and Pl. IX, figs. 1 and 2) is a soft, subgelatinous fungus, forming a brown, crumpled growth with a white, fluffy margin over the surface of timber. As it develops it produces dirty gray to brownish minutely porous strands, which serve for the conduction of water, thus enabling the fungus to spread rapidly over comparatively dry substrata. For this reason it has been frequently termed the "dry-rot fungus." On account of its destructiveness to buildings in Europe it also goes under the German name "Hausschwamm." It rots coniferous timber for the most part.

Coniophora puteana (Pl. VIII, figs. 5 and 6) resembles *Merulius lachrymans* in color and general habit of growth. It is less gelatinous, however, and produces no porous strands. In some situations it produces a smooth, very thin, membranaceous layer on the surface of timber; at other times the surface is quite warted or convolute. The danger from the fungus is enhanced by its ability to rot hardwood as well as coniferous timber.

The fact that we are dealing here with two fungi which are known to be widely distributed in lumberyards in the United States, not only in the region covered by this study, but also along the Pacific coast, coupled with our knowledge of the rather common occurrence and seriousness of the same organisms in buildings throughout the same range, is a cause for grave concern on the part of both lumbermen and builders.

Both fungi can readily be introduced into buildings by means of diseased lumber, and it is very probable that at least some of the outbreaks in comparatively new buildings which have come to the attention of the writer can be attributed to this source.

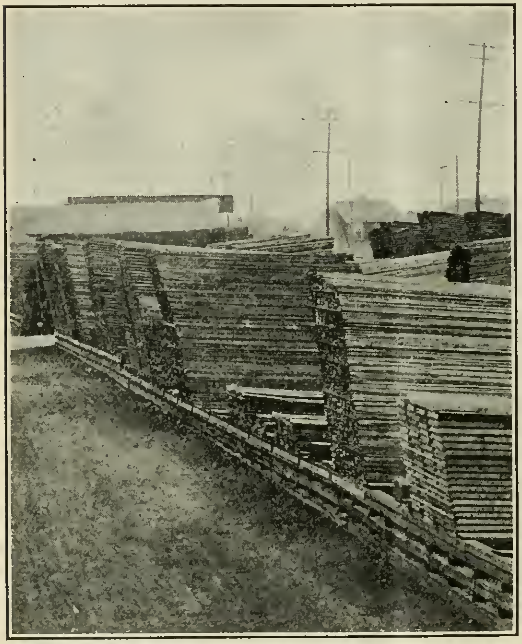


P99F

FIG. 36.—The solid type of built-up plank foundation. This permits air circulation beneath the piles in only one direction. The ends of the stock have been painted to prevent checking.

Besides *Merulius lachrymans* and *Coniophora cerebella* the writer has twice encountered another organism of much the same habit of growth and destructiveness. This organism, the identity of which has not yet been determined, was first found in a retail lumberyard in Alabama and later in a cotton warehouse in Mississippi. The owner of the lumberyard had appealed to the writer for assistance in eradicating a very serious infection, so a careful inspection was made at the first opportunity and the organism was found in great abundance in all three of the open storage sheds, where it had destroyed many of the foundation timbers and also passed upward into the stored lumber (Pl. X, figs. 1–4). The first serious infection noted in this yard occurred six years ago, when two carloads of 6 by 6 pine timbers piled in the open yard were so badly decayed to a height of 6 to 8 feet in the piles as to be rendered useless for building purposes. This material was at once disposed of for firewood. Three years later a further outbreak occurred in two of the open storage sheds and in an addition attached to the small office building. During 1913 a serious infection was also found in a third open shed

According to the owners, the immediate loss of this yard in stock and repairs up to October, 1914, was estimated to be between $1,000 and $2,000. This represents, however, only the actual loss to the company in lumber, figured at wholesale prices, and labor necessary in making repairs. The potential danger to the consumer using such stock, even though but very slightly infected, would amount to very much more than this sum, for a single stick introduced into each of a number of new buildings would occasion an incalculable amount of damage if such timbers happened to be placed in a moist situation favorable for the further development and spread of the fungus.



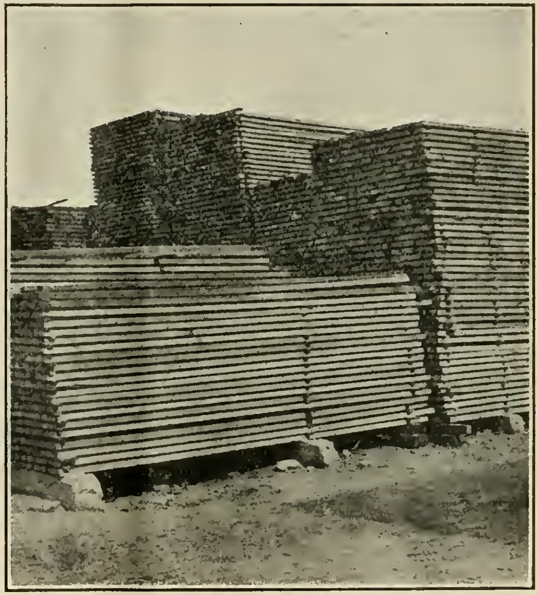
P100F

Fig. 37.—The latticed type of built-up plank foundations. This is an improvement over the solid type, as it allows better ventilation beneath the piles.

As soon as the infections were noted as serious, the company attempted eradication and control measures. In the office building the spread of the fungus has been checked by proper ventilation, and in the sheds the same methods are being applied by removing the cinder fills beneath them and raising the foundations to a height of 18 to 24 inches, placing the sills on brick piers. In future repairs the writer has suggested the application of either mercuric chlorid or some creosote compound to the new timbers.

One member of the company so firmly believed that the cinders used for filling about the yard had been highly favorable to the development and spread of the infection that orders were given to remove all of them from beneath the sheds. While it is possible that the infection may have been introduced by means of the cinders, the rapid growth of the fungus was mainly due to poor ventilation. Cinders have been used by a considerable number of other yards with complete satisfaction. Ashes, however, are not to be recommended. There are records in German literature where ashes used for filling between floors to deaden them have been the source of fungous outbreaks. The case of a cotton warehouse investigated by the writer, where pine flooring laid on flat 2 by 6's resting on ashes was very quickly rotted out by this same fungus (Pl. IX, figs. 3 and 4), likewise offers circumstantial evidence.

The remaining fungus which needs consideration is *Peniophora gigantea* (Fr.) Mass. (Pl. X, figs. 5 and 6). This is a white to pale creamy moldlike growth when immature. When mature it forms a waxy incrustation on the surface of the timber, closely adherent when fresh, but when dry tending to become hard and horny and to curl up at the free edges. This organism is widely distributed, mainly on pine timber, throughout the southern pine belt, and also occurs on conifers in the Rocky Mountain region. In the South it is frequently found in the woods, whence it readily passes to stored lumber. Many lumberyards have been abundantly infected with it ever since they started in business; so long, in fact, that to sever the attachment would be like losing an old acquaintance. From the southern yards it has been introduced northward and is very conspicuous at certain points along the North Atlantic coast (Pl. III, fig. 7). The timber reaches these points mainly by boat. Close storage of the green or partially dried stock in the hold of a vessel during an ocean voyage of perhaps several weeks usually permits a vigorous development of the fungus. As a result of this, infections are so abundant in some of the North Atlantic yards that one would have difficulty in finding any clean material whatever.



P101F

FIG. 38.—Concrete foundations in the retail yard in Alabama shown in figure 15.

It is fortunate that the organism does not approach in destructiveness such forms as have been previously described, else many lumberyards would be doomed immediately. It is a wood-destroying fungus, however, which limits its action to the sapwood. Although the deterioration is comparatively slow, it does weaken the timber to a considerable extent and should be guarded against along with the more dangerous fungi.

WOOD PRESERVATIVES IN THE LUMBERYARD.

Aside from the advisability of preserving permanent structures in the lumberyard by the use of antiseptics applied to or injected into the wood, the question of preserving the lumber itself from incipient infection until it reaches the consumer is one which merits careful thought. During the past decade the use of soda (sodium carbonate or bicarbonate) dips to prevent blue stain has become general throughout the southern pine belt. Within the writer's own experience, sawmill men who in 1909 scoffed at such a measure had within three or four years fallen in with the procession and were enthusiastic advocates of it. As yet the idea of dipping the lumber to prevent infection from true wood-rotting fungi has not been considered by the lumbermen. The soda dip is not sufficient to accomplish the desired end, so we must look elsewhere for a suitable preservative. Mercuric chlorid is a hazardous thing to use on general stock, on account of its extremely poisonous nature, but is very efficient and safe enough for special purposes. Zinc chlorid is objectionable mainly on account of its capacity to attract moisture. Of the remaining colorless salts in use for wood preservation sodium fluorid or some colorless salt of hydrofluoric acid would probably meet the needs of the situation very well. Sodium fluorid is highly toxic to fungi, but can be handled by workmen with no danger of poisoning. It is colorless, easily soluble, and can be handled in any way that the soda dip can. It is more effective than soda and so could readily be substituted for it, thus protecting against both the blue stain and the wood-rotting fungi by a single treatment.

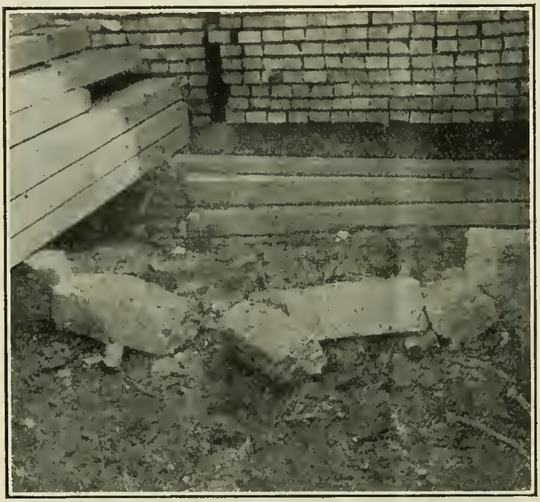

P102F

FIG. 39.—Broken foundations, a result brought about by not reinforcing the concrete. The company later embedded some old 20-pound steel rails in the concrete near the top.

This whole feature of dipping lumber in this way to keep it in a clean condition for the consumer must necessarily involve the close cooperation of millmen, wholesale men, and retailers. The millman may feel indifferent to the proposition, claiming that the deterioration in his yard is not sufficient to warrant it. But this is not merely a mill problem; it is a lumber problem which involves the entire industry and the cooperation of all its members. Even though the mill operator may not in many cases suffer personal monetary loss, still he is often a contributing factor in the losses borne by the retailer and consumer, for incipient decay originating in mill yards and passed over to retail yards may during the later period of storage progress rapidly.

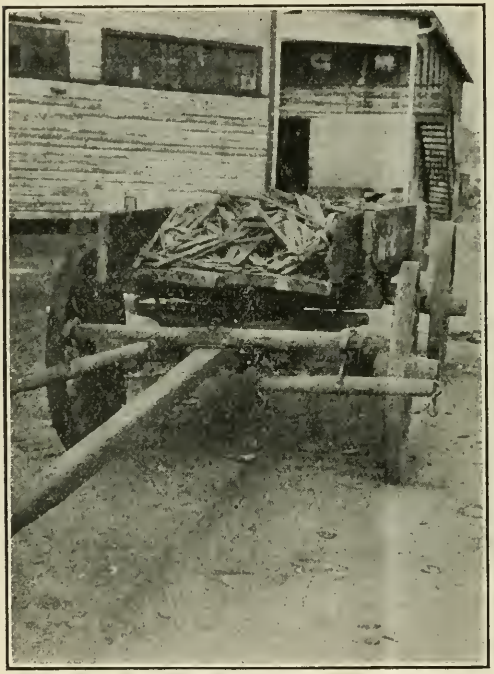
The added cost of treatment would be insignificant in comparison with the benefit derived, and if the lumber trade would take the trouble to explain the benefits to the consumer the slight additional expense would in all probability readily be met by him. Even though it should not be deemed feasible to add the cost of treatment to the finished product, the direct saving accruing to the lumber dealer himself should warrant the expense. It is imperative that something be done by the lumberman to put his product on a more favorable competing basis with other structural materials if he is to safeguard the lumber business for the future.

P104F

FIG. 40.—A southern retail yard, showing a most insanitary way of handling lumber. Structural timbers should never be thrown promiscuously about on the ground in this manner to become infected with wood-destroying fungi.

Another line of endeavor which would reflect favorably on the whole industry is for the lumber dealer to carry in stock, or at least be in a position to produce on order, timber thoroughly treated for construction purposes by certain of the well-known preservative processes. The wood-preserving industry to-day is primarily conducted for the benefit of the heavy consumer. The builder who may need only small quantities of treated stock to place where decay is most likely to occur in his structure is usually unable to obtain it except at prohibitive cost.

The preservative treatment of timber is no magic process and involves no heavy expenditures for necessary apparatus, especially in connection with the simpler methods of treatment. The kyanizing process consists merely in the immersion of the timber in an open wood or concrete tank containing a solution of mercuric chlorid. Any of the other water-soluble salts could be applied in the same way. Creosotes and carbolineums can also be applied in this manner. While in many cases the amount of preservative which can be injected in this way would not be sufficient to fully protect timber in direct contact with the ground, in most cases where treatment is indicated in buildings it would be sufficient. Such treatments could be carried out by any one at any point, and the local treatment of timber would probably be cheaper than when done at a distant centralized plant. In the East, such a local method of treatment is being carried out by at least two lumber dealers within the writer's acquaintance.



P106F

FIG. 41.—Wagon loaded with fragments of lumber to be hauled away. This is the highly commendable practice by which one lumber company keeps its yard clear of débris.

If treated timber were put on the local markets as a standardized product, as readily available to the man who needs 100 feet as to him who uses it by the 100,000 feet, the favorable results experienced by the public in the use of the treated product would in the course of a few years create a demand and be a stepping stone toward a more profitable lumber industry.

BRANDING STRUCTURAL TIMBER.

The discussion now leads us to a consideration of the advantages of branding timber in order to safeguard both the reputable timber producer and the consumer. Such a practice is of particular value in the case of dimension timbers where a standardized uniform product, graded particularly on strength and durability, must be supplied. It is customary at the present time to so brand longleaf pine for export, but the practice is very little followed for the interior trade. Some few retailers stencil their name or brand on certain stock, but this is with them more a matter of advertising than a guaranty of quality, and this must necessarily be the case until a standard and succinct set of grading rules is put into practice by all dealers.

Branding not only puts the company's guaranty of quality behind the product, but indicates as well the kind of timber supplied. Thus, for example, an operator in Douglas fir and western white pine in Idaho could not then possibly confuse his product with southern pine or eastern pine when it reaches the eastern market. For the architect it is very essential to know that the kind of timber he receives accords with the specifications.

The biggest and most enduring reputations in any line of industrial activity are based on the best type of service. When the lumberman who has the highest desire for good service throws his product promiscuously on the market with the lower grade materials, he is at the same time throwing away an industrial asset of no doubtful value. This will become more and more the case as the building public wakes up to the dangers lurking in the use of inferior or fungus-infected timber.

The timber of the United States is a national asset in which the citizens have a certain vested interest which calls for the best utilization possible. The lumberman as guardian of these interests certainly owes to the public no less than his best efforts to convert the forest into a finished product which shall ultimately reach the consumer in prime condition.

CONCLUSIONS.

Improvement of lumber storage conditions can be brought about by modifying present insanitary practices along the following lines:

(1) Strong efforts should be made to store the product on well-drained ground, removed from the possible dangers of floods, high tides, and standing water.

(2) All rotting débris scattered about yards should be collected and burned, no matter whether it be decayed foundation and tramway timbers or stored lumber which has become infected. In the case of yards already filled in to considerable depths with sawdust and other woody débris the situation can be improved by a heavy surfacing with soil, slag, or similar material.

(3) More attention should be given to the foundations of lumber piles in order to insure freedom from decay and better ventilation beneath the stacks. In humid regions the stock should not be piled less than 18 to 24 inches from the ground. Wood blocking used in direct contact with wet ground should be protected by the application of creosote or other antiseptic oils or else replaced by concrete, brick, or other durable materials. Treated horizontal skid timbers would also be highly advantageous, for stock should never be piled in direct contact with diseased timber.

(4) Instead of throwing the "stickers" about on the ground, to become infected, they should be handled carefully and when not in use piled on sound foundations and kept dry as far as possible. If resinous pine or the heartwood of such durable species as white oak or red gum be employed, the danger of possible infection will be greatly decreased.

(5) In most regions lumber should not be close piled in the open, but should be "stuck" with crossers at least 1 inch thick. Lateral spacing is also very desirable. Roofing the piles should not be neglected.

(6) In storage sheds the necessity for piling higher from the ground is very apparent in many cases. The same remedies apply here as for pile foundations in the open. The sheds should be tightly roofed and the siding should not be run down below the bottom of the foundation sills. Free air circulation should be allowed from all sides beneath the inclosure. Only thoroughly dry stock should be stored in close piles under cover.

(7) Should fungous outbreaks occur in storage sheds not constructed to meet sanitary needs the infected foundation timbers should all be torn out and replaced with wood soaked in an antiseptic solution or by concrete or brick. In all cases the new foundations should be so constructed as to keep the lumber well off the ground, and the soil and timber immediately adjoining the infected area should be sprayed or painted with an antiseptic solution of a water-soluble salt, like sodium fluorid, mercuric chlorid, zinc chlorid, or copper sulphate.

Stock which has become infected should never be sold for permanent construction purposes. The placing of such infected stock in buildings may lead to disastrous results, for which the dealer may be held responsible.

(8) The dipping of yard stock in a water solution of sodium fluorid appears advisable from the standpoint of preventing blue stain and incipient infection with wood-destroying fungi during storage.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 511

Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief, and the Office of Farm Management, W. J. SPILLMAN, Chief

Washington, D. C. | PROFESSIONAL PAPER | March 31, 1917

FARM PRACTICE IN THE CULTIVATION OF COTTON

By

H. R. CATES, Scientific Assistant,
Office of Forage-Crop Investigations

CONTENTS

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FARM PRACTICE IN THE CULTIVATION OF COTTON.[1]

By H. R. Cates,

Scientific Assistant, Office of Forage-Crop Investigations.

CONTENTS.

INTRODUCTION.

The data presented in this bulletin[2] represent the first step in a comprehensive study of farm tillage practice in the cultivation of cotton. In this study facts are presented as to what practices are actually employed by the average farmer in the various regions of the South. A study of these practices and the conditions under which they exist should be of value to cotton farmers and investigators in all regions where cotton is grown.

In collecting these data it was found necessary to take into consideration many economic and even sociological factors which might

[1] This work was begun in the Office of Farm Management in 1914 when that office was a division of the Bureau of Plant Industry and has been continued in the Office of Forage-Crop Investigations of the same bureau.

[2] Acknowledgment is due R. W. Pease for assistance rendered while collecting the data presented in this publication.

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have an influence on the tillage practice employed and on the results obtained.

This information was secured by the survey method. Areas throughout the cotton belt which had conditions and practices representative of large regions were selected. In all, 19 areas were studied. (Fig. 1.) These are so located that practically all the conditions and customs found in the cotton belt are represented. Complete farm records were secured from 25 or more farmers in each area. The record shows the general farm practices and conditions, together with a detailed statement of the usual tillage practice employed with cotton on each farm.

These data are presented in tabular form. The general facts are summarized for each area studied and appear in tables which show

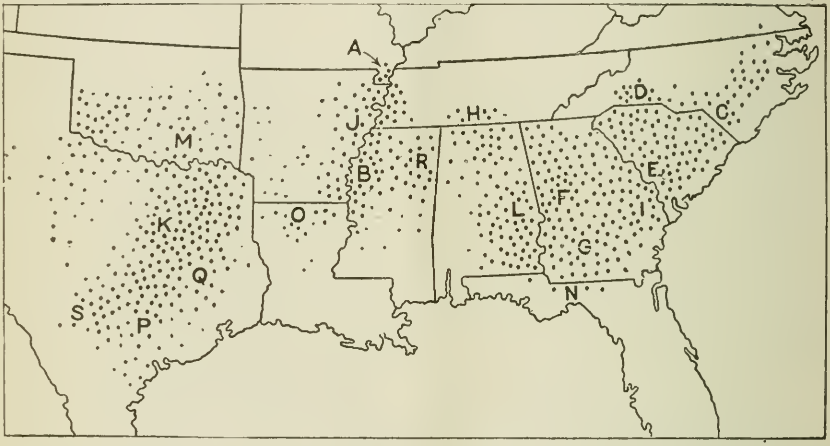

FIG. 1.—Outline map of the southeastern United States, showing the distribution of cotton production by States, each dot representing 20,000 bales (census of 1914). The letters represent the areas in which surveys were made, as follows: *A*, Pemiscot County, Mo.; *B*, Mississippi Delta; *C*, Robeson County, N. C.; *D*, Mecklenburg County, N. C.; *E*, Barnwell County, S. C. *F*, Pike County, Ga.; *G*, Tift County, Ga.; *H*, Giles County, Tenn.; *I*, Bulloch County, Ga.; *J*, St. Francis County, Ark.; *K*, Ellis County, Tex.; *L*, Chambers County, Ala.; *M*, Johnston County, Okla.; *N*, Jefferson County, Fla.; *O*, Lincoln Parish, La.; *P*, Lavaca County, Tex.; *Q*, Houston County, Tex.; *R*, Monroe County, Miss.; *S*, Bexar County, Tex.

the average normal conditions for all areas. The purely tillage data are presented in subsequent tables. A set of tables, one for each area studied, is submitted, giving in detail the tillage practice employed by every cotton grower visited. In addition to these tables a short discussion is included for each area surveyed, presenting the prevailing farm practice, conditions, and customs in the various regions studied.

Summary tables are also presented, showing the average normal tillage practice employed and the normal yields of cotton obtained in each region. The yields of cotton, however, must not be considered as indicating the representative efficiencies of the different methods of tillage employed. Previous investigations with corn[1]

[1] Cates, H. R. Farm practice in the cultivation of corn. U. S. Dept. Agr. Bul. 320, 66 p., 40 fig. 1916.

have shown that crop yields are far more closely related to and influenced by inherent soil fertility and by other farm practices than by the tillage methods.

From such a study as this, therefore, it is not to be expected that a best method of tillage for cotton will be determined which would be applicable under all conditions and circumstances. This paper presents a broad, general idea of what practices are employed in growing cotton under various conditions. It is highly probable that some practices found in one area might be employed elsewhere to advantage. The object of this publication, however, is not to recommend any certain methods for cultivating cotton, but rather to give the reader a detailed knowledge of the various practices which are employed in the different areas, in order that he may adopt any suggestions which might prove advantageous under his conditions.

TABLE I.—*Number of farms surveyed, with the average sizes of farms, average acreage per head of live stock, etc., in nineteen areas in the cotton belt.*

Region surveyed (fig. 1).		Date of survey.	Record taken.	Land in farms.			Cultivated area per head of—		Land per horse.		Cost of farm labor.	
Key letter.	County, State, etc.			Area per farm.	Area cultivated.	Value per acre.	Cattle.	Hogs.	Cultivated.	Intertilled.	Per day.	Per month.
		1914.		*Acres.*	*Acres.*		*Acres.*	*Acres.*	*Acres.*	*Acres.*		
A	Pemiscot, Mo	Aug.	25	159	147	$108.00	34	7	19	16	$1.15	$22.50
B	Mississippi Delta	July	25	1,316	824	55.00	16	8	19	17	.90	16.00
C	Robeson, N. C	June	25	260	123	55.00	37	7	22	19	.70	17.50
D	Mecklenburg, N. C.	June	25	172	115	120.00	12	16	24	14	.70	16.50
E	Barnwell, S. C.	June	25	193	130	34.50	31	9	28	24	.70	15.00
F	Pike, Ga	July	25	144	96	44.00	22	17	27	21	.80	13.50
G	Tift, Ga	June	25	160	83	41.50	13	4	28	21	1.00	19.50
H	Giles, Tenn	July	25	222	136	67.50	8	5	17	12	.80	16.50
I	Bulloch, Ga	June	25	178	85	54.00	7	3	25	22	.95	16.50
J	St. Francis, Ark	Aug.	25	356	226	34.50	19	16	20	18	.95	17.75
K	Ellis, Tex	Sept.	25	194	174	146.50	46	12	24	22	1.30	....
L	Chambers, Ala	July	25	408	231	30.00	18	17	26	22	.70	15.00
M	Johnston, Okla	Sept.	25	239	163	34.00	10	5	25	19	1.15	20.00
N	Jefferson, Fla	July	25	179	101	22.00	12	4	34	29	.70	15.50
O	Lincoln Parish, La.	Aug.	25	125	62	20.50	10	8	20	17	.95	14.00
P	Lavaca, Tex	Sept.	25	210	102	85.50	7	7	15	12	.95	15.50
Q	Houston, Tex	Sept.	25	241	108	26.00	13	15	19	17	1.00	20.00
R	Monroe, Miss	July	25	299	166	35.00	7	8	23	17	.75	16.75
S	Bexar, Tex	Oct.	25	295	130	97.00	14	16	19	19	1.20	20.00

GENERAL STATEMENTS.

In all the general tables the areas included in this study are arranged in order of rank in yield of seed cotton per acre.

The facts presented in Tables I and II have little direct bearing on or relation to tillage other than showing the acreage of cultivated land and intertilled crops per horse and the price of farm labor. Indirectly these data have a very important relation to tillage, in that they show the general farm conditions and practices as found in the various regions surveyed, so that the purely tillage data as presented in subsequent tables may be better interpreted. The data presented in Table II will give some idea regarding the type of farming practiced in the various areas in so far as can be indicated by the crops grown, crop acreage, and crop yields.

TABLE II.—*Normal average acreage per farm and acre yields of various crops on the farms surveyed in each of the nineteen regions studied.*

[The key letters under "Region surveyed" refer to the location of farms studied, as follows: A=Pemiscot County, Mo.; B=Mississippi Delta; C=Robeson County, N. C.; D=Mecklenburg County, N. C.; E=Barnwell County, S. C.; F=Pike County, Ga.; G=Tift County, Ga.; H=Giles County, Tenn.; I=Bulloch County, Ga.; J=St. Francis County, Ark.; K=Ellis County, Tex.; L=Chambers County, Ala.; M=Johnston County, Okla.; N=Jefferson County, Fla.; O=Lincoln Parish, La.; P=Lavaca County, Tex.; Q=Houston County, Tex.; R=Monroe County, Miss.; S=Bexar County, Tex.]

Region surveyed (fig. 1).	Cotton.		Corn.		Oats.		Sugar cane.		Sweet potato.	
	Per farm.	Yield.	Per farm.	Yield.	Per farm.	Yield.	Per farm.	Yield.	Per farm.	Yield.
	Acres.	*Pounds.*	*Acres.*	*Bushels.*	*Acres.*	*Bushels.*	*Acres.*		*Acres.*	*Bushels.*
A	71	1,200	57	37						
B	540.5	1,034	197	30.5	39	42				
C	65.5	1,006	39.5	24	7	30				
D	35	958	32	22.5	17	26				
E	62.5	925	47.5	16.5	12	22				
F	49.5	904	24	20.5	12	35.5				
G	34.5	881	21.5	21	10	27			1.5	109
H	26.5	860	69.5	35.5	9.5	24.5				
I	40.5	816	29	21	6	28				
J	145.5	767	59	28	3	27	0.5	a 100	.5	87
K	132	684	25.5	27	10.5	40	1.5	b 3.5		
L	138	676	54.5	19.5	21.5	25.5				
M	72.5	676	44	25	17.5	29	6.5	c 28	1	183.5
N	29	664.5	50	12.5	4	18	1	0	1	145.5
O	24	644	21	17	2	16.5	.5	b 208	1	114.5
P	51.5	642	30	26.5			2.5	b 2.5		
Q	58.5	610	35	17	1.5	38.5			.5	105.5
R	75.5	586	46.5	24.5	9.5	21.5	2	a 100	1.5	79.5
S	75.5	472	34	24.5	4	25	15	b 2.5		

Region surveyed (fig. 1).	Alfalfa.		Peanut.		Cowpea.		Irish potato.		Pasture and all other crops per farm.
	Per farm.	Yield.	Per farm.	Yield.	Per farm.	Yield.	Per farm.	Yield.	
	Acres.	*Tons.*	*Acres.*	*Bushels.*	*Acres.*	*Tons.*	*Acres.*	*Bushels.*	*Acres.*
A	18	4							1.5
B	3	3			13.5	0			31.5
C									11
D	d 8	1							23
E									8.5
F					5	0			5.5
G			4.5	16					10.5
H	21.5	1.5							8.5
I			3.5	0					5.5
J					10.5	1.5	0.55	73	6.5
K									4.5
L									17
M	4	2							17.5
N			6.5	27.5					9
O			6.5	27.5					6
P	e 13.5	1							4
Q			1	25	2.5	1			8.5
R	1.5	3.5	2	32.5	14	1	1	127	13
S									1.5

a Gallons. b Tons. c Bushels. d Crimson clover. e Prairie grass.

SUBSOILING.

Subsoiling is the process of breaking up the subsoil without mixing it with the topsoil. It is most often accomplished by plowing a furrow with an ordinary turning plow and then running a smaller shovel plow in the bottom of this furrow. Throughout the cotton belt, where the land as prepared for cotton is often plowed into beds instead of being plowed flat, subsoiling is practiced only in those furrows immediately under the row.

Table III indicates that where a light or loamy soil is underlain with a heavy clay subsoil, as in Robeson County, N. C., subsoiling is more often employed with good results than where the subsoil is light or where the topsoil is a heavy clay.

TABLE III.—*Practices with cotton in nineteen regions surveyed, showing data in regard to subsoiling, drainage, and tillage before plowing.*

The key letters under "Region surveyed" refer to the location of farms studied, as follows: A=Pemiscot County, Mo.; B=Mississippi Delta; C=Robeson County, N. C.; D=Mecklenburg County, N. C.; E Barnwell County, S. C.; F=Pike County, Ga.; G=Tift County, Ga.; H=Giles County, Tenn.; I=Bulloch County, Ga.; J=St. Francis County, Ark.; K=Ellis County, Tex.; L=Chambers County, Ala; M=Johnston County, Okla.; N=Jefferson County, Fla.; O=Lincoln Parish, La.; P=Lavaca County, Tex.; Q=Houston County, Tex.; R=Monroe County, Miss.; S=Bexar County, Tex.]

Region surveyed (fig. 1).	Subsoiling.				Drainage.				Tillage before plowing.			
	Farmers practicing.	Average depth.	Opinions of farmers reporting.		Terraces or surface ditches.	Open ditches.	Part tiled.	All tiled.	Farmers practicing.	Farmers using.		
			Good.	Bad.						Stalk cutter.	Harrow.	
											Disk.	Spike-tooth.
	Per cent.	*Inches.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Per cent.*	*P. ct.*	*P. ct.*	*P. ct.*
A					20	48			88	88	12	
B	8	8	100		20	76	8	4	92	92	4	
C	48	11½	91.5	8.5	12	84	8		100	88	88	
D	60	10	46.5	53.5	100		16		52	40	12	
E	24	10	33.5	66.5	20	44			76	76	4	
F	44	11½	91	9	52	44	4		92	92		
G	16	11½	50	25		84			100	96	16	
H	12	10½	100		50	40	16		44	32	4	8
I	8	12	100		24	56			88	84	4	
J	4	10	100		60	40			84	84		
K					72	28			76	72	4	
L	48	10	58.5	41.5	100	28	12		40	40		
M									84	84		
N	4				12	44			60	60		
O	20	10	40	60	52	48			60	60		
P					12				100	100		
Q	12		66.5	33.5	16				76	64	12	
R	40	10	70	30	88	4	4		76	76		
S									80	76		4

DRAINAGE.

The kind of drainage employed is governed by the type of soil, the topography, the amount of rainfall, and the value of land. There are three principal types of drainage employed (Table III): Terraces and surface ditches, open ditches, and tile drains.

Surface ditches and terraces are employed where the rainfall is heavy and the land rolling. In most sections of the cotton belt the organic content of the soil is very low and the rainfall high. In those areas having a clay or clay-loam soil and a rolling topography numerous surface ditches and terraces are required to carry off the surface water and prevent erosion. (Fig. 2.)

Open ditches are employed in flat or level lands having poor drainage conditions. These ditches answer the same purpose as tile drains. They usually surround the fields and occupy considerable land that otherwise might be cultivated.

Tile drainage is employed instead of open ditches where the relative value of the land is sufficient to warrant the extra expense of the tile.

TILLAGE BEFORE PLOWING.

The rotations practiced throughout the cotton belt are such that cotton generally follows cotton or corn. Tillage before plowing is necessary to break up the stalks left from the previous crop except in a few areas where the stalks do not grow to a sufficient size to interfere with tillage operations. For this work a stalk cutter (fig. 3) is most often employed. In areas where the stalks grow excep-

FIG. 2.—A cotton field laid off in terraces. Where the land is rolling, with a clay type of soil, as shown in this field in Mecklenburg County, N. C., numerous terraces and surface ditches are required to carry off the surface water and prevent erosion.

tionally large and weeds and grass are abundant, both the stalk cutter and disk harrow are at times used. Little thought is given to the benefits derived from pulverizing the surface soil before breaking.

PLOWING.

Whether land be plowed in the fall or spring is governed largely by the previous crop and the type of soil. Where cotton follows small grain or some sod-forming crop, the land is more frequently plowed in the fall than where cotton follows a cultivated crop. Heavy clay soils are more often plowed in the fall than light sandy soils. (Table IV.)

The rotations practiced in the South are such that cotton generally follows a cultivated crop, and most of the land is plowed in the spring. Many heavy rains occur during the winter months, and when land is plowed in the fall it is hard to prevent erosion. This is particularly true in the areas having a clay or clay-loam soil and a rolling topography. Another reason — and probably the principal one—why more land for cotton is not plowed in the fall is because the previous crop is not harvested in the fall in time to permit such plowing to be done.

FIG. 3.—A stalk cutter. By using this implement before plowing, the stalks and other vegetable matter on the land are chopped up so that they decay more readily and do not interfere with cultivation.

It is customary when plowing in the fall to plow the land slightly deeper than if plowed in the spring. For all the areas surveyed the average depth of fall plowing is 6 inches, while the average depth of spring plowing is $5\frac{3}{10}$ inches.

TABLE IV.—*Tillage practices with cotton in nineteen regions surveyed, showing data in regard to plowing.*

Region surveyed (fig. 1).		Fall plowing.		Spring plowing.		Farmers plowing land—		Plows used by farmers.			
Key letter.	County, State, etc.	Farmers practicing.	Depth.	Farmers practicing.	Depth.	Level.	Into beds.	1-horse.	2-horse.	3-horse.	4-horse.
		Per cent.	*Inches.*	*Per cent.*	*Inches.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
A	Pemiscot, Mo.	0	....	100	5	60	40	0	76	24	0
B	Mississippi Delta.	16	4	84	5	24	76	0	76	8	16
C	Robeson, N. C.	4	$7\frac{1}{2}$	96	$6\frac{1}{2}$	56	44	36	64	0	0
D	Mecklenburg, N. C.	52	$6\frac{1}{2}$	48	$5\frac{1}{2}$	80	20	4	88	8	0
E	Barnwell, S. C.	0	....	100	6	100	0	52	48	0	0
F	Pike, Ga.	56	$6\frac{1}{2}$	44	$5\frac{1}{2}$	80	20	12	88	0	0
G	Tift, Ga.	16	$7\frac{1}{2}$	84	7	100	0	4	92	4	0
H	Giles, Tenn.	12	5	88	$5\frac{1}{2}$	100	0	0	96	4	0
I	Bulloch, Ga.	0	....	100	7	96	4	32	68	0	0
J	St. Francis, Ark.	0	....	100	4	4	96	56	44	0	0
K	Ellis, Tex.	4	6	96	4	4	96	0	4	0	96
L	Chambers, Ala.	0	....	100	$5\frac{1}{2}$	72	28	28	72	0	0
M	Johnston, Okla.	8	4	92	$4\frac{1}{2}$	60	40	0	60	36	4
N	Jefferson, Fla.	8	10	92	$4\frac{1}{2}$	52	48	48	52	0	0
O	Lincoln Parish, La.	0	....	100	$4\frac{1}{2}$	28	72	32	68	0	0
P	Lavaca, Tex.	68	5	32	5	0	100	0	80	0	20
Q	Houston, Tex.	8	7	92	4	8	92	0	96	0	4
R	Monroe, Miss.	4	$3\frac{1}{2}$	96	5	20	80	12	84	0	4
S	Bexar, Tex.	92	6	8	7	92	8	[a] 4	12	36	48

[a] Five-horse plow.

With reference to the relation of depth of plowing to yield of cotton a compilation of the data from all the records taken has been made (Table V). These data show clearly that there is no relation between depth of plowing and yield of cotton. However, there may be an associated factor, since the depth of plowing for cotton is largely governed by the type of soil. The light sandy or loamy soils are plowed slightly deeper than the heavy clay soils. It is probable that the light soils are plowed deeper than the heavier soils largely because

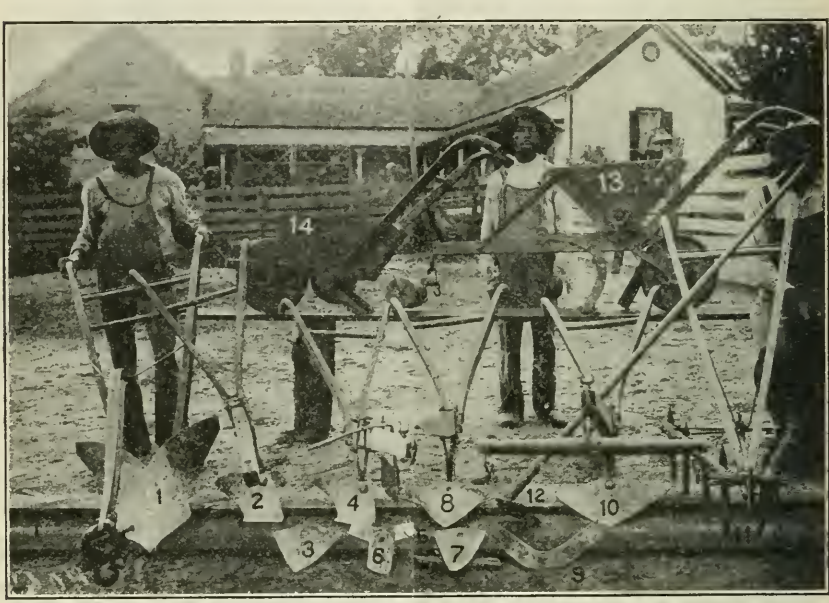

FIG. 4.—Some types of tillage implements employed in growing cotton: 1, Middle buster, or lister; 2, Georgia stock with half shovel or turning plow; 3, small solid sweep; 4, Georgia stock with half shovel and fender attached for use in barring off; 5, 10-inch heel sweep, or heel scrape; 6, diamond scooter; 7, broad shovel; 8, Georgia stock with solid sweep and 18-inch heel sweep attached; 9, 18-inch heel sweep; 10, Georgia stock with 18-inch solid sweep attached; 11, 1-horse spike-tooth or harrow-tooth cultivator; 12, cotton hoe; 13, fertilizer distributor; 14, cotton planter.

a plow will normally run deeper in sand or loam than it will in clay, and not because any effort is made to plow the light soils deeper.

TABLE V.—*Relation of depth of plowing to acre yields of cotton.*

Areas.	Depth of plowing.														Average yield.
	3 inches.		4 inches.		5 inches.		6 inches.		7 inches.		8 inches.		9 inches.		
	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	
		Lbs.		*Lbs.*		*Lbs.*		*Lbs.*		*Lbs.*		*Lbs.*		*Lbs.*	*Lbs.*
Delta area	2	1,350	23	1,135	15	1,140	6	1,000	2	950	2	1,000	0	0	1,117
South Atlantic division	1	500	33	792	40	817	54	836	20	825	38	980	14	896	854
Intermediate areas	18	642	25	736	35	697	15	693	4	975	3	916	0	0	714
Southwestern division	22	620	47	601	24	620	23	593	2	550	7	650	0	0	617
Total	43	3,112	128	3,264	114	3,274	98	3,122	28	3,300	50	3,546	14	896	....
Average	....	778	....	816	....	819	....	780	....	825	....	886	....	896	....

PREPARATION AFTER PLOWING.

The type of soil and the prevailing tillage methods determine what implements are used in preparing the cotton land after plowing. Table VI is presented to show these implements. It also shows the areas in which each implement is used and to what extent it is employed.

TABLE VI.—*Practices with cotton in nineteen regions surveyed relating to tillage after plowing and before planting, showing implements used and average number of workings.*

[The key letters under "Region surveyed" refer to the location of farms studied, as follows: A=Pemiscot County, Mo.; B=Mississippi Delta; C=Robeson County, N. C.; D=Mecklenburg County, N. C.; E=Barnwell County, S. C.; F=Pike County, Ga.; G=Tift County, Ga.; H=Giles County, Tenn.; I=Bulloch County, Ga.; J=St. Francis County, Ark.; K=Ellis County, Tex.; L=Chambers County, Ala.; M=Johnston County, Okla.; N=Jefferson County, Fla.; O=Lincoln Parish, La.; P=Lavaca County, Tex.; Q=Houston County, Tex.; R=Monroe County, Miss.; S=Bexar County, Tex.]

Region surveyed. (fig. 1).	Harrow.						Roller.		Cultivator.	
	Spike-tooth.		Disk.		Spring-tooth.					
	Farms using.	Of all work.	Farms using.	Of all work.	Farms using.	Of all work.	Farms using.	Of all work.	Farms using.	Of all work.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
A	72	38.5	20	8	...	...	8	3	20	7.5
B	88	47	8	6	8	4	...	...	20	10
C	...	...	32	10	...	...	...	...	...	...
D	84	30	64	21	...	...	...	...	...	...
E	...	...	40	12	...	...	...	...	...	...
F	20	8	60	19.5	...	...	...	...	...	...
G	20	6	48	14.5	...	...	...	...	52	15.5
H	80	33	44	13.5	...	...	20	6	16	5
I	...	...	24	7	...	...	...	...	68	20
J	96	70.5	...	...	...	...	...	...	...	...
K	68	38.5	...	...	...	...	...	...	8	4.5
L	...	...	...	...	...	...	...	...	20	10.5
M	72	44.5	16	9	...	...	...	...	...	...
N	8	5	...	...	...	...	...	...	...	...
O	28	12.5	...	...	...	...	...	...	...	...
P	88	48	...	...	...	...	...	...	...	...
Q	96	51	...	...	...	...	...	...	8	4.5
R	48	29	12	7.5	...	...	...	...	12	7.5
S	84	40.5	8	3.5	...	...	...	...	36	15.5

Region surveyed (fig. 1).	Log drag.		For bedding.				1-horse 1-shovel plow to lay off rows.		Fertilizer distributor.		Average number of workings.
			Turning plow.		Lister.						
	Farms using.	Of all work.	Farms using.	Of all work.	Farms using.	Of all work.	Farms using.	Of all work.	Farms using.	Of all work.	
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
A	48	18.5	...	...	64	24.5	...	...	...	...	2.5
B	8	4	56	29	...	...	...	...	...	...	2
C	...	...	100	33	36	12	36	12	100	33	3
D	...	...	76	21	...	...	...	...	100	28	3.5
E	...	...	96	28.5	...	...	100	30	100	29.5	3.5
F	...	...	60	19.5	60	20	...	...	100	33	3
G	...	...	36	15.5	...	...	68	20	100	28.5	3.5
H	8	2.5	80	24.5	...	...	40	12	12	3.5	3.5
I	...	...	52	17.5	20	5.5	76	21.5	100	28.5	3.5
J	...	...	44	29.5	...	...	...	...	0	...	1.5
K	...	...	...	...	...	...	...	...	[a] 100	57	2
L	...	...	84	27.5	60	20	28	9	100	33	3
M	...	...	...	...	...	...	56	31	[a] 28	15.5	2
N	...	...	81	35.5	...	...	56	22	88	37.5	1.5
O	...	...	88	40	...	...	36	16.5	84	31	2.5
P	...	...	...	...	...	...	...	...	[a] 96	52	2
Q	...	...	76	40.5	...	...	...	...	[a] 8	4	2
R	...	...	20	12	24	14.5	...	...	48	29.5	1.5
S	...	...	...	...	...	...	...	...	[a] 96	40.5	2.5

[a] Two-horse 1-row lister planter.

The spike-tooth and disk harrows are extensively used on every type of soil. In most areas the turning plow is used for bedding the land. Quite often the middle buster, or lister, is employed for this purpose. This implement is also used to some extent for plowing land in parts of Texas and Oklahoma. Fertilizer distributors (fig. 4) are used in all areas where fertilizer is applied to cotton. This implement is often employed instead of a shovel plow for opening up the rows.

PLANTING.

The time of planting cotton is governed largely by the type of soil and the climatic conditions. Clay soils do not warm up as rapidly in

FIG. 5.—Chopping cotton. The seed is sown in drills, and at the first or second cultivation the plants are chopped to a stand with a hoe, leaving one stalk every 12 to 15 inches in the drill.

the spring as light sandy soils; therefore, cotton is planted later on the heavy clay soils, other conditions being equal.

It is customary to plant cotton on a slightly raised bed. There are two reasons for this: (1) It is much easier to thin the cotton to a stand when it is planted on a bed than when it is planted level, cotton being thinned by hand with a hoe and much labor being involved (fig. 5). (2) Another reason for planting cotton on a bed is that when land is bedded up, more surface is exposed to the air and sunshine, and consequently the land warms up more quickly, thereby giving the cotton an earlier start. Bedding up also affords better drainage conditions, which must be considered in many parts of the cotton belt. In only a few areas, where dry weather prevails during the growing season, is cotton ever listed.

Cotton is always sown in drills and thinned to a stand at the first or second cultivation. The rows range from 3 to 4 feet apart and the stalks are left one or two to the hill, with the hills from 12 to 18 inches apart in the row. Usually from 2 to 4 pecks of seed are planted per acre. More seed is usually planted per acre on clay soils which bake readily than on light sandy soils. Very little cotton is planted by hand, 1-horse 1-row planters being generally used (fig. 6). In some areas of Texas and Oklahoma the 2-horse 1-row planter is used, and quite often a lister is attached to the planter (fig. 7). This same type of planter with a different attachment is used for planting corn.

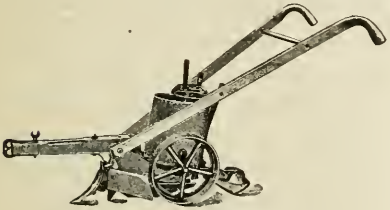

FIG. 6.—A type of 1-horse cotton planter.

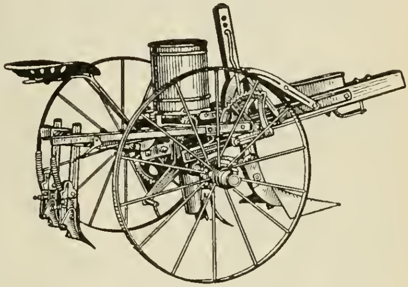

FIG. 7.—A combined lister and planter, an implement used for planting cotton in parts of Oklahoma and Texas, especially in those areas where dry weather prevails during the growing season.

Details as to the time and methods of planting cotton will be found in Table VII.

TABLE VII.—*Tillage practices with cotton in nineteen regions surveyed, showing the dates and methods of planting.*

[The key letters under "Region surveyed" refer to the location of farms studied, as follows: A=Pemiscot County, Mo.; B=Mississippi Delta; C=Robeson County, N. C.; D=Mecklenburg County, N. C.; E=Barnwell County, S. C.; F=Pike County, Ga.; G=Tift County, Ga.; H=Giles County, Tenn.; I=Bulloch County, Ga.; J=St. Francis County, Ark.; K=Ellis County, Tex.; L=Chambers County, Ala.; M=Johnston County, Okla.; N=Jefferson County, Fla.; O=Lincoln Parish, La.; P=Lavaca County, Tex.; Q=Houston County, Tex.; R=Monroe County, Miss.; S=Bexar County, Tex.]

Region surveyed (fig. 1).	Date.		Farmers planting [a]—			Average distance apart.		Average space per hill.	Seed per acre.	Planters used by farmers.		
											2-horse.	
	Average.	Range.	Level.	On beds.	Listing.	Rows.	Hills.			1-horse.	2-row.	1-row.
			P. ct.	*P. ct.*	*P. ct.*	*Feet.*	*In.*	*Sq. ft.*	*Peck.*	*P. ct.*	*P. ct.*	*P. ct.*
A	Apr. 21	Apr. 10 to May 10	......	100	......	3½	16	5	4	60	40	......
B	Apr. 11	Mar. 25 to Apr. 30	16	84	......	4	17	6	4	96	4	......
C	Apr. 14	Apr. 8 to Apr. 20	8	92	......	4	13	4	4	100	......	......
D	Apr. 23	Apr. 15 to May 5	......	100	......	3½	12½	3.5	4	100	......	......
E	Apr. 11	Mar. 15 to Apr. 30	......	100	......	4	15½	5	4	......	......	......
F	Apr. 15	Apr. 1 to May 1	16	84	......	3½	13	3.5	5	100	......	......
G	Apr. 4	Mar. 15 to Apr. 20	28	64	8	4	16½	5.5	2.5	100	......	......
H	Apr. 15	Mar. 10 to Apr. 30	20	80	......	3	13	3.5	5.5	100	......	......
I	Apr. 1	Mar. 15 to Apr. 15	4	84	12	4	16½	5.5	3	100	......	......
J	Apr. 25	Apr. 1 to May 20	4	96	......	3½	14	4.5	5.5	100	......	......
K	Apr. 13	Apr. 1 to May 15	8	92	......	3	13	3.5	2.5	......	[b] 4	96
L	Apr. 11	Mar. 25 to May 1	......	100	......	3½	13½	4	5	100	......	......
M	Apr. 21	Apr. 1 to June 8	16	64	20	3½	15½	4.5	2.5	64	4	32
N	Apr. 1	Mar. 1 to Apr. 15	8	92	......	4	13	4	4	92	4	[c] 4
O	Apr. 18	Apr. 1 to May 15	......	100	......	4	14	4.5	4	100	......	......
P	Mar. 25	Mar. 1 to May 1	......	100	......	3½	13	4	5.5	8	......	92
Q	Apr. 16	Mar. 30 to May 30	4	96	......	3½	12½	3.5	3	92	......	8
R	Apr. 15	Apr. 1 to May 1	4	96	......	3½	15	4.5	4	96	......	4
S	Mar. 25	Mar. 1 to Apr. 15	40	20	40	3½	18½	5.5	3	......	4	96

[a] All planted with drill. [b] Three-horse 1-row planter. [c] Hand planter.

NORMAL AVERAGES OF FARM CONDITIONS.

Normal averages of farm operations and conditions are presented in Table VIII.

Of the areas studied, the nine having the highest acre yield of seed cotton have an average normal acre yield of 954 pounds, while the nine areas having the lowest acre yield of seed cotton average 628 pounds. This great difference in yield is probably due to many factors. In the areas where higher yields are made it is probable that the inherent fertility of the soil is greater, and the sociological, economic, and climatic conditions are such that, generally speaking, better farming prevails. Furthermore, it is probable that the additional commercial fertilizer used and the extra tillage given account to a large extent for the increased yields, even where other conditions are equal.

The average depth of plowing for the nine areas having the highest yield of seed cotton is 6 inches, while the average depth for the nine areas having the lowest yield of seed cotton per acre is only 4½ inches. It is probable, however, that this is only an associated factor rather than a correlated one, and the real cause for the variation in depth of plowing may be found in the type of soil. The high yields of cotton are made on sandy-loam or clay-loam soils. These soils are usually plowed deeper than the heavier clay soils, on which the yields of cotton are somewhat lower.

After plowing and before planting the average number of workings for the nine areas having the highest average yield of cotton is three, while for the nine areas having the lowest average yield of cotton the average number of workings is only two.

One cause of this difference is the fact that in the higher yielding areas 70 per cent of the farmers use commercial fertilizers and in the lower yielding areas only 43 per cent of the farmers use such fertilizers. The fertilizer is applied with a distributor, the operation being recorded as equivalent to a working.

In the nine areas having the highest average yield of seed cotton per acre the average number of cultivations after planting is six, while the average number of cultivations given in the nine areas having the lowest normal yield of seed cotton per acre is only five. It appears that there is a direct correlation between the amount of cultivation given after planting and the yield of seed cotton per acre. (Table X.)

The number of hand cultivations is approximately the same for all areas. It is customary to go over the cotton with a hoe at the first or second cultivation and thin to a stand (see fig. 5), then at the third or fourth cultivation to go over the row again and take out any weeds or any extra cotton stalks that may have been left.

TABLE VIII.—*Practices with cotton in nineteen regions surveyed, showing average data in regard to depths of plowing, number of cultivations, price of land, commercial fertilizer used, and normal acre yields.*

Region surveyed (fig. 1). Key letter.	Region surveyed (fig. 1). County, State, etc.	Depth of plowing.	Average number of— Workings after plowing and before planting.	Average number of— Cultivations after planting.	Average number of— Hand cultivations.	Price of land.	Commercial fertilizer used. Farms applying.	Commercial fertilizer used. Per acre.	Yield.
		Inches.					*P. ct.*	*Pounds.*	*Pounds.*
A	Pemiscot, Mo.	5	2.5	6	2	$108.00	0	....	1,200
B	Mississippi Delta	4½	2	9.5	2.5	55.00	24	130	1,034
C	Robeson, N. C.	6½	3	6.5	2.5	55.00	100	676	1,006
D	Mecklenburg, N. C.	6	3.5	5.5	2	120.00	100	330	958
E	Barnwell, S. C.	6	3.5	6.5	2.5	34.50	100	666	925
F	Pike, Ga.	6	3	5.5	2	44.00	100	416	904
G	Tift, Ga.	7	3.5	5.5	2	41.50	100	342	881
H	Giles, Tenn.	5½	3.5	5.5	2	67.50	12	200	860
I	Bulloch, Ga.	7	3.5	5.5	2	54.00	100	506	816
J	St. Francis, Ark.	4	1.5	5	2	34.50	0	....	767
K	Ellis, Tex.	4	2	5	2.5	146.50	0	....	684
L	Chambers, Ala.	5½	3	5.5	2	30.00	100	312	676
M	Johnston, Okla.	4	2	5.5	2	34.00	4	300	676
N	Jefferson, Fla.	5	1.5	5	1.5	22.00	92	286	665
O	Lincoln Parish, La.	4½	2.5	5	2	20.50	84	205	644
P	Lavaca, Tex.	4½	2	4.5	2	85.50	0	....	642
Q	Houston, Tex.	4½	2	4.5	2	26.00	60	202	610
R	Monroe, Miss.	4½	1.5	5	2	35.00	48	202	586
S	Bexar, Tex.	6	2.5	4.5	2	97.00	0	....	472

SUMMARY SHOWING AVERAGES BY REGIONS AND DIVISIONS.

Regions and divisions.	Area in farms. Total.	Area in farms. Cultivated.	Per acre. Price of land.	Per acre. Normal yield.	Depth of plowing.	Average number of— Workings after plowing and before planting.	Average number of— Cultivations after planting.	Average number of— Hand cultivations.	Commercial fertilizer used. Farms applying.	Commercial fertilizer used. Per acre.
Regions:	*Acres.*	*Acres.*		*Pounds.*	*Inches.*				*P. ct.*	*Lbs.*
Nine best	311	193	$64.50	954	6	3	6	2	70	408
Nine poorest	245	137	55 00	628	4.5	2	5	2	43	251
Average of all areas studied	282	168	58.50	790	5	2.5	5.5	2	54	341
Divisions:										
Delta area	212	121	50.00	854	6	3	5.5	2	99	442
South Atlantic division	737	486	81.50	1,117	5	2.5	7.5	2.5	12	130
Intermediate areas	251	148	39.50	714	4.5	2	5	2	36	202
Southwestern division	236	135	78.00	617	5	2	5	2	13	251

The price of land and the yields of cotton per acre are somewhat related, but there is only a slight correlation. (See Tables VIII and X.) However, the average acre value of land for the nine areas having the highest acre yield of seed cotton is $64.50, while the average acre value for the nine having the lowest average normal yields is $55. Aside from crop yields there are many economic and sociological features which enter into the determination of the market price of land; for example, land in the Mississippi Delta will produce as much or more corn per acre than the land in the northern Mississippi Valley corn belt, yet the environment and conditions in the Delta are such that the land sells for less than half what the corn-belt land will bring. It is probable that in the cotton belt the economic and social features of an area have more to do with regulating the price of land than do crop yields.

THE RELATION OF CROP ROTATIONS TO CROP YIELDS.

Generally crop rotations affect crop yields. The rotations having the largest percentage of those crops which add organic matter to the soil, such as hay or pasture, are usually conducive to the best yields. Regarding this factor, the data from all the records taken have been compiled in Table IX to show the relation between the crop yield and the normal average percentage of cultivated land in cotton. When the combined data from all the areas are compared (Table IX) there appears to be no effect on crop yields of growing a larger or a smaller percentage of the land to cotton. In the South Atlantic division, however, where large quantities of commercial fertilizers are applied each year, better crop yields are secured where 40 per cent or more of the land is in cotton. This is probably due to the large quantities of fertilizers used, a part of which remains in the soil from year to year.

TABLE IX.—*Relation of percentage of cultivated land in cotton and normal acre yields of cotton.*

Areas.	Percentage of cultivated land in cotton.															
	29 or less.		30 to 39.		40 to 49.		50 to 59.		60 to 69.		70 to 79.		80 to 89.		90 and over.	
	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.
		Lbs.		*Lbs.*		*Lbs.*		*Lbs.*		*Lbs.*		*Lbs.*		*Lbs.*		*Lbs.*
Delta areas	3	1,133	6	1,316	5	1,280	10	1,060	14	964	10	1,160	2	1,225	0	0
South Atlantic division	36	801	33	864	45	901	53	844	23	878	10	780	0	0	0	0
Intermediate areas	38	737	13	696	13	611	23	645	5	730	6	691	2	975	0	0
Southwestern division	6	800	16	618	21	609	30	533	24	600	16	590	11	631	1	500
Total	83	3,471	68	3,494	84	3,401	116	3,082	66	3,172	42	3,221	15	2,821	1	500
Average	....	868	....	874	....	850	....	771	....	793	....	805	....	940	....	500

It is generally found that the inherent fertility of the soil and the climatic conditions largely determine the crop yields. Another important factor in determining the crop yield in many parts of the cotton belt is the quantity of fertilizers used. Of the areas studied, in the nine having the highest yields of cotton 70 per cent of the farms surveyed use commercial fertilizer, and the average application per acre for a cotton crop is 408 pounds. In the nine areas having the lowest yields of cotton, only 43 per cent of the farms surveyed use commercial fertilizer, and the average application per acre for a cotton crop is 251 pounds.

THE RELATION OF TILLAGE AND PRICE OF LAND TO CROP YIELDS.

In Table X the data are arranged to show the relation of tillage after planting and the price of land to yields of cotton per acre. This table shows that there is little correlation between the price of land and the acre yields of cotton, but a very decided relation between the amount of tillage given after planting and the yields of cotton per acre. In a recent study of farm practice in the cultivation of corn [1] it was found that there is little or no relation between yields of corn and the amount of tillage given after planting. Previous investigations [2] have shown that with corn, if weeds be eliminated, any sort of tillage after planting is of minor consideration. Recent experiments have indicated that in growing cotton ordinary tillage operations are of minor consideration other than for controlling weeds. It would appear, however, from these studies that extra tillage does increase the yields of cotton, which, generally speaking, is not found to be true with corn.

TABLE X.—*The relation of tillage and price of land to normal acre yields of cotton.*

Acre value of farm.	Number of cultivations.										Average.	
	3 or less.		4 or 5.		6 or 7.		8 or 9.		10 or more.			
	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Farms.	Yield.	Price.	Yield.
		Lbs.		*Lbs.*		*Lbs.*		*Lbs.*		*Lbs.*		*Lbs.*
$30 or less	2	900	99	636	50	767	3	833	1	800	$21.80	787
$31 to $50	1	400	61	725	52	940	7	930	6	967	41.80	792
$51 to $70	0	0	12	720	18	958	5	910	1	1,400	60.00	997
$71 to $90	4	538	26	665	14	843	2	900	3	1,166	77.50	822
$91 to $110	0	0	28	887	16	994	2	1,300	0	0	100.00	1,060
$111 to $130	1	500	10	875	8	970	1	1,200	0	0	124.25	886
$131 to $150	1	400	16	774	8	800	0	0	0	0	148.00	658
$151 to $170	0	0	2	725	2	875	0	0	0	0	162.50	800
$171 to $190	0	0	2	875	1	1,000	0	0	0	0	175.00	937
$190 or over	0	0	2	750	2	925	0	0	0	0	212.50	837
Total	9	2,738	258	7,632	171	9,072	20	6,073	11	4,333	....	......
Average	....	548	....	763	....	907	....	1,012	....	1,083	....	......

In consideration of the different root systems of the cotton and corn plants, this might be expected. The corn plant has many shallow fibrous roots, many of which are destroyed by cultivation, and it is probable that by cultivating corn the injury to the corn plants by destroying these numerous roots is as great or greater than the benefits of liberating plant food and conserving moisture.

[1] Cates, H. R. Farm practice in the cultivation of corn. U. S. Dept. Agr. Bul. 320, 66 p., 40 fig. 1916.

[2] Cates, J. S., and Cox, H. R. The weed factor in the cultivation of corn. U. S. Dept. Agr., Bur. Plant Indus. Bul. 257, 35 p., 10 fig. 1912.

The cotton plant, on the other hand, has a deep taproot system, with very few shallow surface roots. Extra cultivation therefore does very little injury to the cotton roots, and the advantages of cultivation, such as aerating the soil, liberating plant food, and conserving moisture, are all secured without detriment to the cotton plant.

GROUPS OF COTTON-GROWING AREAS.

The areas in which cotton-tillage surveys were made may be grouped into four divisions (Table IX): (1) The Delta areas; (2) the South Atlantic division; (3) the Intermediate areas; and (4) the Southwestern division.

The Delta area studies were made in Yazoo, Sharkey, and Washington Counties, Miss., and in Pemiscot County, Mo.

In this division, especially in Mississippi, the farms are very large and are operated by the tenant system. Usually the owner lives in a near-by town or village and visits the farm only occasionally to direct the work. A hired superintendent lives on the farm and has direct control of it and the supervision of the tenants.

The soils in the Delta areas are very fertile, and little commercial fertilizer is used. Average crop yields are higher than in any other area studied. More tillage after planting is given cotton in this area than in the other regions surveyed. This is due largely to the fact that many of the fields are infested with nut-grass, and to control it extra tillage is required.

The South Atlantic division is composed of North Carolina, South Carolina, Georgia, Florida, and Alabama. In this division eight surveys were made. The farms are of medium size and are largely operated by the tenant system, but under the direct supervision of the owners. The prevailing system is to furnish each tenant with a mule and 20 or 25 acres of land, the greater part of which is planted to cotton. Cotton is the most profitable crop in this area, and one reason for a 1-horse tenant system is that when each tenant has only a 1-horse crop he grows all the cotton he and his family can pick. With a 2-horse crop the tenant could not increase his cotton acreage because of scarcity of labor for harvesting, so he would necessarily grow other crops, such as corn or oats; consequently a larger percentage of the land is cultivated in cotton by the 1-horse tenant system, with a relatively larger return for the landowner.

Considering crop yields, land values in this division appear fairly low; but in this connection the fact that large applications of commercial fertilizers are required to produce such yields tends to alleviate the apparent low price of land. Throughout this division the prevailing soil type is the Norfolk sandy loam, but it grades into a clay loam in those areas farther from the coast.

Land is plowed deeper in this division than in the other areas studied. This is probably due to the fact that the soils are predominantly of a sandy type, and soils of this texture are, generally speaking, broken deeper than clay soils.

In this division it will be noted that more tillage is given after plowing and before planting. This is due primarily to the use of a fertilizer distributor, which is not so extensively employed in other divisions.

The Intermediate areas include Giles County, Tenn., Monroe County, Miss., St. Francis County, Ark., and Lincoln Parish, La. In each of these areas there are varying conditions. Part of the land in each region is rolling and rough, with irregularly shaped fields and small farms, and part is broad level bottom land divided into large farms. The upland rolling farms are usually worked by the owners or by tenants who supervise their own work. Crop yields are not so good as on the bottom-land farms, which are often very large and are usually worked by tenants under the supervision of the owner or a hired manager.

Little uniformity is found in these areas with regard to general conditions and tillage practice.

The Southwestern division includes Texas and Oklahoma. Five areas were surveyed in this division. Here the predominating soil type is a clay loam. Most of the farms are operated by the owners or by tenants who supervise their own farming. Heavier teams and implements are employed both for preparing the land and for cultivating the crop. The land is comparatively fertile, and little or no commercial fertilizer is used. The crop yields are probably governed here more by climatic conditions than by soil fertility or tillage practice.

The depth of breaking land and the amount of tillage given both before and after planting are about the average, yet crop yields are below the normal average for other areas studied. This is probably due primarily to scant rainfall.

GENERAL FARM PRACTICES AND CONDITIONS.

SURVEY IN PEMISCOT COUNTY, MO.

Pemiscot County is located in the extreme southeastern part of Missouri along the Mississippi River. The tillage records for this county (Table XI) were taken near Caruthersville. This is a typical Delta region. The soil and subsoil are a silty clay loam and very fertile. No commercial fertilizer is used, and stable manure is not considered valuable. The country is exceptionally flat, and the soil is such that no surface or tile drainage is required. The excess water is collected by broad open ditches and runs into central canals, which are dug by the county.

TABLE XI.—*Tillage practices with cotton in Pemiscot County, Mo., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 9 and 11 to 18 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing: Depth (inches).	Plowing: Level.	Plowing: Into beds.	Tillage after plowing and before planting: Bedded with lister.	Harrow: Disk.	Harrow: Spike-tooth.	2-horse log drag, roller.	2-horse disk cultivator.	All workings.	Tillage after planting: 2-horse 2-shovel cultivator, with scrapes.	Spike-tooth harrow.	2-horse cultivator with sweeps: 4-shovel.	2-horse cultivator with sweeps: 2-shovel.	1-horse sweep or scrape.	Cultivator: 2-horse 4-shovel, with 2 sweeps and 2 shovels.	Cultivator: Disk.	Cultivator: 2-horse spring-tooth.	All cultivations.	Yield (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	6	1	...	a2	...	1	3	...	3	1	...	4	5	6	2, 3	...	...	6	1,200
2	4	...	1	...	...	...	2	1	2	...	...	...	3	...	...	1, 2, 4, 5	...	5	1,200
3	8	1	...	a2	...	1, 3	5	4	5	...	...	2, 3, 6, 7	...	...	4, 5	1	...	7	1,000
4	6	...	1	...	...	1, 2	3	...	3	1, 3	...	2 to 6	...	...	...	...	...	6	1,000
5	4	1	...	3	1	2, 4	...	...	4	...	...	2 to 5	6	...	...	...	1	6	1,500
6	5	1	...	3	2	1, 4	...	...	4	...	...	...	...	...	...	...	1 to 9	9	1,200
7	3	1	...	2	1	3	...	...	3	1	...	2 to 5	...	...	...	...	...	5	1,500
8	5	...	1	...	...	1	2	...	2	...	...	2 to 5	...	1	...	...	...	5	800
9	4	1	...	2	1	...	3	...	3	...	...	1 to 5	...	...	...	...	...	5	1,500
10	4	...	1	...	...	1	2	...	2	1	...	2 to 5	...	...	...	...	...	5	1,400
11	5	1	...	...	...	...	2	1	2	...	...	2, 3, 4	...	...	...	1, 5	...	5	1,000
12	5	1	...	...	...	1, 3	4	2	4	2	1	3, 4, 5	...	...	...	6	...	6	1,200
13	5	...	1	1	...	2	...	...	2	1	...	2 to 5	6	7	...	...	...	7	1,000
14	5	1	...	1	...	2	...	...	2	...	...	...	...	1, 3, 4, 5	...	...	b 2	5	1,300
15	6	...	1	...	...	...	1	...	1	1	...	...	4	6	2, 3	5	...	6	1,000
16	8	1	...	1	...	...	2	...	2	1	...	2, 3, 4	...	...	...	5	...	5	1,000
17	6	1	...	2	...	1, 3	4	...	4	3	1, 2	4, 5	7	...	...	6	...	7	1,200
18	4	1	...	1	...	...	2	...	2	1	...	2, 3	4, 5	7	...	6	...	7	1,000
19	4	...	1	1	...	2	...	...	2	1	...	2 to 5	...	...	...	...	...	5	1,500
20	5	...	1	...	...	...	1	...	1	1	...	2, 3, 4	...	...	...	...	...	4	1,500
21	4	...	1	1	...	2	...	...	2	1	...	2 to 6	...	...	...	...	...	6	1,250
22	4	...	1	1	...	2	...	...	2	1	...	2 to 5	...	...	...	...	...	5	1,000
23	4	1	...	1	...	2	...	...	2	...	...	1 to 6	...	...	...	...	...	6	1,750
24	4	1	...	2	...	1, 3	...	...	3	1	...	2, 3, 4	...	...	...	5	...	5	1,000
25	...	1	...	...	1	2	...	3	3	...	...	2 to 5	6	...	...	1	...	6	1,000
Farms using, per ct.	...	60	40	64	20	72	56	20	...	60	8	84	32	24	12	40	12	...	...
Average.	5	...	...	...	...	...	...	...	2.5	...	...	...	...	...	...	...	...	6	1,200

a Shovel plow. b One-horse spring-tooth cultivator.

Large tracts of land are owned by a few men. This land is divided into farms of 100 to 150 acres and rented to white tenants on a cash basis. About 50 per cent of the farms are worked by tenants. Often the land is rented for cash and then sublet on a share basis.

The principal crops grown are cotton, corn, and alfalfa. No set rotations are practiced, and cotton is often planted on the same land for a number of years. Alfalfa does exceptionally well here and is grown on every farm. The yield is from 2 to 5 tons of hay per acre. The cotton yields are high, but the quantity produced is limited by the labor available for picking.

Cotton and hay are the principal money crops, although some corn is sold. Enough hogs are kept to supply meat for home demands, but few cattle are raised. Not enough fruit and truck is produced to supply the local markets.

The tillage methods employed with cotton combine features of both the corn and the cotton belts, in that the heavy teams of the corn belt are employed, with the type of implements and methods

FIG. 8.—Harrowing a field before plowing the land for cotton. In many parts of the cotton belt a disk harrow is used to cut up the old cotton stalks before plowing the land.

found in the cotton belt. In preparing the land the old cotton and corn stalks are cut up with a stalk cutter or disk harrow before plowing. (Fig. 8.) The land is then broken with a 2-horse or 3-horse plow. About half the land is broken level. Later it is harrowed with a spike-tooth harrow and bedded with a middle buster, or lister. These beds are slightly leveled off with a log drag and the cotton planted on the bed. About half the farmers bed the land as it is broken. This is done with a lister or with a turning plow. The beds are harrowed with a spike-tooth harrow (fig. 9) and then leveled off with a log drag before planting the cotton. Cotton is always planted on a slight bed and either a 1-horse 1-row or 2-horse 2-row planter is used. The rows average $3\frac{1}{2}$ feet apart, and about a bushel of seed is planted per acre. After chopping, the stalks are left from 15 to 20 inches apart in the drill.

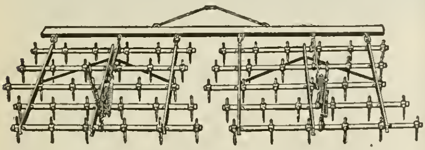

FIG. 9.—A spike-tooth harrow, well adapted for preparing a seed bed on any type of soil.

The cultivating after planting is largely by means of 2-horse implements. The first cultivation is given with a 2-horse 1-row cultivator equipped with two scrapes, one of which runs on each side of the row and scrapes the soil away from the cotton plants, leaving them on a small ridge, where they can be easily chopped to a stand with a hoe. After chopping, the next cultivation is given with a 2-horse 4-shovel cultivator equipped with four 6-inch or 8-inch sweeps instead of shovels (fig. 10). These sweeps push the earth back to the cotton plants. Three or four cultivations are given with this implement, and the size of the sweep is increased at each cultivation up to 12 or 14 inches.

For the last cultivation this same implement is used, equipped with only two large sweeps. (See fig. 11.) Often a 2-horse disk cul-

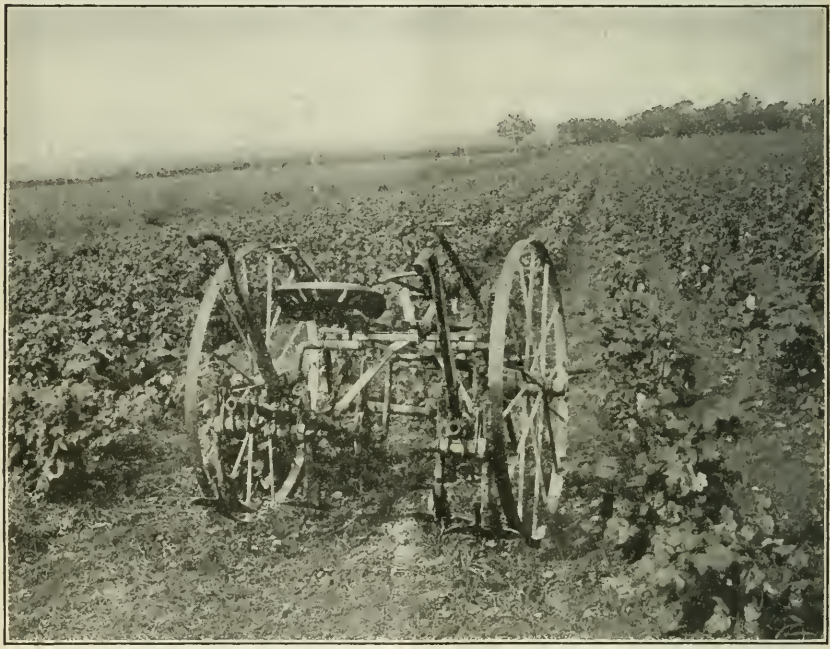

FIG. 10.—A 2-horse 4-shovel cultivator with small sweeps attached instead of shovels, extensively used for the tillage of cotton in Texas, Oklahoma, and other sections of the cotton belt.

tivator is used for the last cultivation. A few farmers employ a 1-horse sweep in cultivating, but most of the work is done with 2-horse implements. The cotton is left slightly ridged at the last cultivation. (See fig. 12.) In all, five or six cultivations are given. At the third or fourth cultivation the rows are again gone over with a hoe and any weeds or extra cotton stalks are chopped out. No cover crops are grown.

The principal varieties of cotton grown are Georgia Big Boll, King's Improved, Rowden, and Mebane.

The most troublesome weeds are cocklebur, crab-grass, careless weed, morning-glory, and pigweed.

SURVEY IN THE MISSISSIPPI DELTA.

The tillage records for the Mississippi Delta (Table XII) were taken in Yazoo County, near Yazoo City, Miss., in Washington County, near Greenville, Miss., and in Sharkey County, near Rolling Fork, Miss.

The Mississippi Delta extends approximately from Vicksburg to the northern boundary of the State, and conditions throughout the region are fairly uniform. The topography is exceptionally level and drainage is by open ditches which surround the fields. Practically none of the land is tile drained. The soil is a dark-brown silt loam and very fertile. No commercial fertilizer is used and little stable manure is produced.

The farms are large and only about 60 per cent of the land is cultivated. All the farming is done by negro tenants under the supervision of the owner or a hired manager.

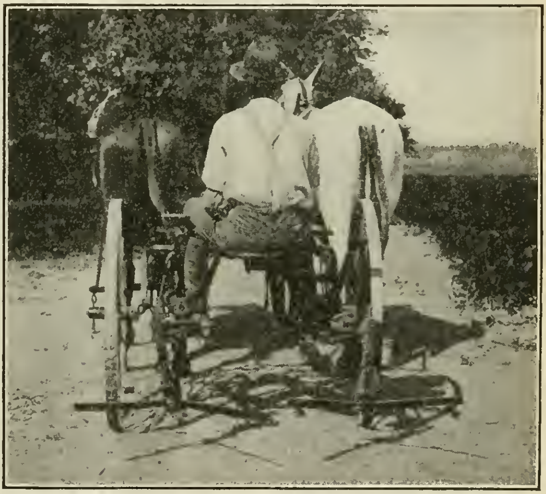

FIG. 11.—A 2-horse 2-shovel cultivator equipped with long sweeps instead of shovels, used for the tillage of cotton in Pemiscot County, Mo., and other sections of the cotton belt.

Cotton is the principal crop grown and is the only source of income on most farms. Nearly every farmer grows a few oats, which are fed on the farm. No set rotations are practiced, and on many of the farms cotton has been grown on the same land continuously for 75 years, but still produces a profitable yield. On some farms a 3-year rotation is partly maintained, in which cotton is grown two years followed by corn one year. Cowpeas are sown in the corn at the last cultivation and the vines are plowed under after the corn is harvested.

Not enough cattle and hogs are kept to supply home demands and none are raised for market. Very little fruit or truck is grown.

In preparing the land for cotton 2-horse teams are used. After the cotton is picked the old stalks are cut up with a stalk cutter (fig. 3) and the land is plowed in the early spring, most of it being bedded as broken. Either a 2-horse turning plow or a lister is used. If the land is not bedded as broken it is bedded before the cotton is planted. If a lister is used for breaking, the beds are plowed up a little higher by running one furrow with a 2-horse turning plow on each side of the bed. These beds are then harrowed down with a spike-tooth harrow until they are only 3 or 4 inches high. Sometimes a disk harrow or 1-horse cultivator may be used for leveling down the bed.

The cotton is planted on this slight bed with a 1-horse planter. The rows are about 4 feet apart and 3 to 4 pecks of seed are planted per acre. When chopped, the stalks are left from 15 to 20 inches apart in the rows.

TABLE XII.—*Tillage practices with cotton in the Mississippi Delta, showing depths of plowing, implements used, number of times each is used, and normal acre yields.*

[In columns 5 to 10 and 12 to 21 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing: Depth (inches).	Plowing: Level.	Plowing: Into beds.	Tillage after plowing and before planting: Bedded with turning plow.	Tillage after plowing and before planting: Harrow: Disk.	Tillage after plowing and before planting: Harrow: Spike-tooth.	Tillage after plowing and before planting: 1-horse spring-tooth cultivator.	Tillage after plowing and before planting: Log drag.	Tillage after plowing and before planting: 1-horse 5-shovel cultivator.	Tillage after plowing and before planting: All workings.	Tillage after plowing: Harrow: Spike-tooth.	Tillage after plowing: Harrow: 1-horse side.	Tillage after plowing: Cultivator: 1-horse, 5-shovel, with sweeps.	Tillage after plowing: Cultivator: 1-horse, 2-shovel.	Tillage after plowing: Cultivator: 2-horse spring-tooth.	Tillage after plowing: Cultivator: 2-horse 4-shovel, with—Shovels.	Tillage after plowing: Cultivator: 2-horse 4-shovel, with—Sweeps.	Tillage after plowing: 2-horse lister.	Tillage after plowing: 1-horse sweep.	Tillage after plowing: 1-horse turning plow.	Tillage after plowing: All cultivations.	Yield (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	5		1			1			2	2	1		13, 14, 15		(a)	3	4	5	8, 11		15	800
2	5		1			1				1		1, 5	2, 4, 6 to 10						3		10	1,500
3	3	1		1		2				2	1	2	3 to 7								7	1,200
4	5	1		b 2		1		3		3	1		9 to 12		3 to 8			2			12	1,000
5	6	1		b 1, 2			3			3		1, 2, 3, 6	4, 5, 7, 8, 9								9	750
6	4	1		b 2	1	3				3	1		10	7, 8, 9	2, 3	4	5, 6				10	1,200
7	5		1				1			1			1, 3, 4, 6, 7	2, 5							7	1,200
8	4		1	1		2				2			1, 8			2	3 to 7				8	800
9	5		1	1		2				2			1, 3, 5, 7, 9	(c)							9	1,500
10	4		1			1				1		3	5 to 8		(d) 4				2	1	8	400
11	4		1	1					2	2			1, 8	2, 3			4 to 7				8	1,100
12	5		1	1		2			3	3			1, 5, 7, 8	2, 4, 6			3				8	1,500
13	4		1			1				1		4, 7								(e)	9	1,400
14	4		1			1, 2				2	1				(f)						12	1,200
15	4		1	1		2				2		1			2, 3, 5	4			6		6	1,100
16	5		1			1				1		1, 2	4 to 10		3						10	800
17	4		1			1		2		2		1, 2, 3		4 to 9							9	750
18	4		1	1		2				2	g1		1, 2, 3, 5, 7, 9	(h)							10	1,400
19	7	1			1, 2	3				3					(i)		(k)				11	800
20	4		1	1		2				2		2, 3	1, 4 to 11								11	900
21	4		1	1		2				2		1, 4	5, 7 to 10						2, 3, 6		10	800
22	5		1	1		2				2		1, 2	3 to 8								9	800
23	4		1	1		2			3	3			1, 2, 4, 5	6 to 9				3			9	950
24	6		1			1, 2				2		1	3 to 7						2		7	900
25	7	1		2		1			3	2	1				2, 3		4 to 12				12	1,100
Farms using, per cent		76	24	60	8	88	8	8	20		28	48	76	32	36	16	28	12	24	8		
																44						
Average	4½									2											9½	1,034

a Cultivations 2, 6, 7, 9, 10, and 12.
b Lister.
c Cultivations 2, 4, 6, and 8.
d One-horse spring-tooth cultivator.
e Cultivations 1, 2, 3, 5, 6, 8, and 9.
f Cultivations 2 and 3 with 1-horse spring-tooth cultivator; cultivations 4 to 12 with 2-horse spring-tooth cultivator.
g Weeder.
h Cultivations 4, 6, 8, and 10.
i Cultivations 2, 3, 4, 6, 8, and 10.
k Cultivations 5, 7, 9, and 11.

Weeds are very troublesome in the Delta, and more cultivation is given cotton here after planting than in any other region surveyed. Just after the cotton comes up it is usually harrowed with a spike-tooth harrow or with a 1-horse harrow-tooth cultivator. After this, cultivators equipped with sweeps are largely used, 1-horse implements predominating. The 1-horse 5-shovel cultivator equipped with small sweeps instead of shovels is the most popular. The 2-horse spring-tooth cultivator and 2-horse 4-shovel cultivator, with sweeps and shovels, and the 1-horse 2-shovel cultivator are also extensively used. Cotton is cultivated every week or 10 days during the growing

FIG. 12.—A cotton field, showing the rows of plants in ridges. At the last cultivations it is customary to plow a little dirt toward the plants, leaving them slightly ridged up.

season, a total of 9 or 10 cultivations being given. The crop is chopped to a stand at the second cultivation, and then hoed once or twice more during the season to chop out any weeds and extra stalks of cotton.

No cover crops are grown, but where organic matter is added to the soil in any way the crop yields are increased.

The principal varieties of cotton grown are Trice, Simpkins' Prolific, Dodds, Metcalf, and Express.

The most prevalent and troublesome weeds are nut-grass, crab-grass, cocklebur, morning-glory, Johnson grass, careless weed, and coffee weed.

SURVEY IN ROBESON COUNTY, N. C.

Robeson County is located in the southeastern central part of North Carolina in the Coastal Plain area. The tillage records for this county (Table XIII) were taken near Lumberton and Rowland.

This is a typical cotton section. The country is very flat, and in some sections swampy. The soil is a sandy loam with a clay subsoil. It is easily cultivated, and where organic matter is added and large quantities of commercial fertilizers are used good crop yields are obtained.

The farm conditions in this region are typical for southeastern North Carolina and northeastern South Carolina. The farms are rather large, and most of the farming is done by tenants, usually on a share basis and under the supervision of the owners. In the system most often practiced the tenant furnishes the labor and gets one-third of the crop; all else, including work stock, fertilizers, equipment, and a house for the tenant, is furnished by the landlord.

TABLE XIII.—*Tillage practices with cotton in Robeson County, N. C., showing depths of plowing, implements used in order of use, number of time each is used, and normal acre yields.*

[In columns 5 to 9 and 11 to 15 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.						Tillage after planting.						Yield (pounds).
	Depth (inches).	Level.	Into beds.	Disk harrow.	Rows run with 1-horse 1-shovel plow.	Lister.	Fertilizer distributor.	Bedded with turning plow.	All workings.	1-horse spring-tooth cultivator.	Weeder.	Spike-tooth harrow or harrow-tooth cultivator.	1-horse sweep or scrape.	1-horse 1-shovel plow.	All cultivations.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	4		1				1	2	2				1 to 7	2	7	1,350
2	6	1			1		2	3	3			1	2 to 6		6	900
3	5	1				1	2	3	3				1 to 5		5	1,200
4	6		1		1		2	3	3				1 to 6		6	750
5	6		1		1		2	3	3	1			1 to 6		6	900
6	6		1		1		2	3	3		1		2, 4, 5, 6	[a] 3	6	1,000
7	5		1				1	2	2			1	2 to 6	3	6	1,000
8	7	1		1		2	3	4	4			1	2 to 8		8	1,000
9	4		1			1	2	3	3				1 to 7		7	600
10	6		1				1	2	2	1			2 to 6		6	1,000
11	8		1		1		2	3	3				1 to 7		7	1,000
12	8	1		1			2	3	3			1, 2	3 to 6		6	1,200
13	7½	1		1	2		3	4	4		1, 2, 3		4 to 8		8	1,100
14	4		1				1	2	2	1	2, 3, 4			[b] 5	5	1,000
15	8	1		1		2	3	4	4				1 to 6		6	900
16	8	1		1	2		3	4	4		1, 2		3 to 7		7	1,000
17	4		1				1	2	2				1 to 7		7	1,500
18	6		1				1	2	2				1 to 6		6	1,000
19	8	1		1		2	3	4	4			1	2 to 8		8	1,150
20	7	1		1		2	3	4	4			1	2 to 5		5	800
21	9	1		1	2		3	4	4		1		2 to 7		7	1,000
22	7	1				1	2	3	3			1	2 to 8		8	1,000
23	8	1			1		2	3	3			1	2 to 7		7	800
24	7	1				1	2	3	3	2			1, 3, 4, 5	2	5	1,000
25	5	1				1	2	3	3				1 to 7		7	1,000
Farms using (per cent)		56	44	32	36	36	100	100		16	16	32	100	20		
Average	6½								3						6½	1,006

[a] One-horse 4-shovel cultivator. [b] Turning plow.

Some rural improvements have been made in this county. The land is drained by means of open ditches which surround the fields, and the farmers have cooperated in establishing canal systems to dispose of the water. Practically none of the land is tile drained. In some parts of the county good sand-clay roads are maintained, but most of the roads are in poor condition.

The farmers in this region employ a 1-crop system, and no definite rotations are practiced. Cotton is the principal crop and is planted on the most productive land. The average farm surveyed cultivates 65½ acres of cotton and produces an average yield of 1,006 pounds of seed cotton per acre. Corn is the crop of next importance, the average farmer growing 39½ acres, with an average yield of 24 bushels per acre. Nearly every farmer grows a few acres of oats, which are often cut for hay while the grain is in the dough stage. The average yield of oats is 30 bushels per acre. Cowpeas or peanuts are often planted between the corn rows at the last cultivation and used as pasture for cattle or hogs in the fall. Cowpeas are also sown after oats and the vines cut for hay. A few farmers grow tobacco, but not extensively. Nearly every farmer grows a few sweet potatoes, watermelons, and cantaloupes, and some garden truck. Not enough fruit is produced for home use. Some cattle and hogs are marketed, but the principal source of farm income is cotton.

The tillage methods with cotton in this county are very uniform. The old cotton and corn stalks are cut up during the winter months with a stalk cutter or disk harrow, or with both. The plowing is done in the spring with 1-horse or 2-horse plows. About half the land is broken level and the other half thrown into beds when broken. If the land is rough or cloddy after breaking a disk harrow is sometimes used, but this is not often necessary. If the land is broken level the rows are laid off with a 1-horse turning plow, using two furrows to the row, or with a 2-horse middle buster or lister, which requires only one furrow. The fertilizer is then placed in the bottom of this furrow with a distributor (in between the ridges, where the land was bedded as broken) and a ridge made on the fertilizer by throwing a furrow from each side with a turning plow. The cotton is planted on this ridge with a 1-horse planter. The average width of rows is 4 feet, and, after thinning, the stalks are left in the rows from 15 to 18 inches apart.

In cultivating after planting, a weeder (fig. 13) or spike-tooth harrow is often used just before or after the cotton comes up. After this practically all the cultivating is done with a 1-horse sweep or scrape.

For the first cultivation an 8-inch sweep is used, running one furrow on each side of the row. The cotton is then chopped to a stand, leaving one stalk every 15 or 18 inches. For the next cultivation a 12-inch sweep is used and the entire middle plowed out, which requires three furrows for each row. Some farmers use a sweep next to the cotton and break out the middle with a 1-horse shovel plow. After this every other middle is cultivated with the sweep every week, making a complete cultivation every two weeks. (See fig. 14.) Six or seven cultivations are given during the season. The crop is gone over with the hoe again at the third or fourth cultivation, and any weeds or extra cotton stalks are chopped out.

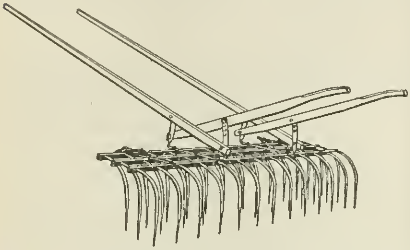

FIG. 13.—A weeder used in many areas for the first cultivation of cotton.

Few cover crops are grown. Organic matter is supplied by crop residues and by grass and weeds which are plowed under. Heavy applications of commercial fertilizers are used by every farmer visited. The average quantity applied per acre for a cotton crop is 676 pounds. This is usually applied in the drill before planting time, but sometimes two applications are made. When nitrate of soda is used it is applied later in the season.

FIG. 14.—A cotton field cultivated by the alternate-middle method. In Robeson County, N. C., cotton is grown by cultivating alternate middles each week, making a complete cultivation every two weeks.

The principal varieties of cotton grown are Bates, Cook's Improved, and Simpkins' Improved. The most prevalent and troublesome weeds found in this county are crab-grass (see fig. 15), cocklebur, smartweed, and pigweed.

SURVEY IN MECKLENBURG COUNTY, N. C.

Mecklenburg County is located in the southwestern part of North Carolina and is one of the best developed agricultural counties in the State. The tillage records for this county (Table XIV) were taken near Charlotte.

The soil is a reddish clay loam with a clay subsoil. Where sufficient organic matter is present and commercial fertilizers are used, good crop yields are obtained. The country is rolling, and many terraces and open ditches are required to carry off the surface water and prevent erosion. (See fig. 2.) Very little of the land is tile drained.

The rural improvements in this county are exceptionally good. Most of the leading roads have been macadamized and are kept in excellent condition. Good schools are maintained. The farmers

Fig. 15.—A cotton field containing crab-grass, one of the most troublesome weeds found in such fields.

have good houses, which are kept well painted. In all, the country is attractive and appears prosperous.

The farms are of good size, averaging 172 acres, with 115 acres cultivated. Many of the farms are worked by tenants, but usually under the supervision of the owner.

No set rotations are practiced, but cultivated crops are usually followed by small grain. The principal crops grown are cotton, corn, wheat, oats, and clover.

Cotton is the principal money crop and the yields obtained are good. Enough corn is grown to feed the live stock and supply local demands. Oats are usually cut for hay while in the dough stage. Not enough wheat is grown for home use, none being produced on many farms. Cowpeas are sown after oats and the vines cut for hay. Watermelons are grown extensively in this county and shipped to northern markets. Enough truck and fruit is produced to supply local markets. Some cattle and hogs are sold, but the principal source of income is cotton.

TABLE XIV.—*Tillage practices with cotton in Mecklenburg County, N. C., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 8 and 10 to 16 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.					Tillage after planting.								Yield (pounds).
	Depth (inches.)	Level.	Into beds.	Disk harrow.	1-horse 1-shovel plow or fertilizer distributor.	Bedded with turning plow.	Spike-tooth harrow.	All workings.	Spike-tooth harrow.	Weeder.	1-horse harrow-tooth cultivator or side harrow.	1-horse sweep or scrape.	Cultivator. 1-horse 4-shovel.	Cultivator. 2-horse 6-shovel.	Cultivator. 2-horse 8-shovel.	All cultivations.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	6	1			1	2	3	3		1	2,3			4 to 7		7	750
2	4½		1		1	2	3	3			1,2	3,4,5				5	750
3	8	1		1	2	3	4	4		1	2	3			4,5	5	1,000
4	5	1		1	2	3	4	4	1		2	4	3,5,6			6	800
5	8	1		1,3	2			3		1,2			3 to 6			6	1,200
6	8	1		1	2	3	4	4		1,2		5,6	3,4,7			7	900
7	6	1		1	2	3	4	4			1,4	2,3,5				5	1,400
8	6	1		1,4	3		2	4					4,5	1,2,3		5	750
9	8	1		1	2	3		3	1		2,3		4,5,6			6	1,000
10	5	1			3	2	1	3	1		2	5	3,4			5	600
11	5	1		1	2,3	4	5	5	1			3,4,5	2			5	1,000
12	4		1		1	2	3	3			1	2,3,4				4	1,200
13	8	1		1,4	3		2	4		1,2	3,4,5	6,7				7	1,000
14	6	1		1	2	3	4	4			1	2,3,4				4	1,000
15	5	1		1	2	3	4	4		1	2	5,6	3,4			6	750
16	6	1		3	2		1	3		1	2,3	4,5				5	1,000
17	6		1		1	*a* 2	3	3		1,2			3 to 6			6	850
18	6		1		1	2	3	3	1			3 to 6		2		6	750
19	5	1		1	2	3	4	4		1	2		3 to 6			6	1,100
20	6	1		3	1,2			3	1		2,3,4	5,6				6	750
21	8	1		1	2	4	*b* 4	4		1	2				3 to 6	6	1,000
22	5	1		2	1			2		1	2	3,4				4	750
23	5	1			2	3	1,4	4	1		2,4,8	3,5,6,7				8	1,400
24	4½	1			1	*a* 2	3	3	1		2	3 to 6				6	750
25	9		1		1	2	3	3	2,3	1	4	5,6,7				7	1,500
Farms using, per cent.		80	20	64	100	76	84		36	48	76	72	40	12	8		
Average	6							3.5								5.5	958

a Lister. *b* Log drag.

In preparing a seed bed for cotton on land that was in cotton or corn the previous year, the old stalks are cut up with a stalk cutter or disk harrow before plowing the land in the spring. Where cotton follows sod or stubble, the land is usually broken level in the fall about 6 inches deep with a 2-horse turning plow. After plowing, the land is harrowed with a disk harrow. In the spring the rows are laid off with a 1-horse shovel plow and the fertilizer applied with a distributor in the furrow. A bed is made on this fertilizer with a 1-horse turning plow. Then this bed is harrowed with a spike-tooth harrow, which makes it almost level, and cotton is planted on the bed.

The rows average 3½ feet apart, and 4 pecks of seed are planted per acre. After chopping, the stalks are left from 12 to 15 inches apart in the drill.

The cultivating after planting is largely with 1-horse implements. Just after the cotton is up a spike-tooth harrow or weeder is used. The next cultivation is given with a 1-horse harrow-tooth cultivator known as a side harrow (fig. 16), and then the cotton is chopped to a stand. After this, the cultivating is done with a 1-horse sweep or with a 1-horse 6-shovel cultivator. In all, five or six cultivations are given. At the third or fourth cultivation the field is usually gone over again with a hoe, to chop out any weeds or extra cotton stalks.

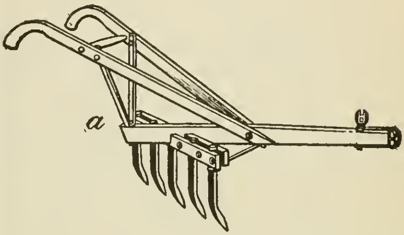

FIG. 16.—A 1-horse side harrow or spike-tooth cultivator, an implement extensively used for the tillage of cotton in Mecklenburg Co., N. C., and other parts of the South.

Crimson clover is often grown as a cover crop after corn and cotton. This clover is pastured during the early spring and then plowed under to supply organic matter to the soil. Many farmers use commercial fertilizer, and the average application for cotton is 330 pounds per acre.

The principal varieties of cotton grown are Cook's Improved, Simpkins' Prolific, and King's Improved.

The most troublesome and prevalent weeds in this county are crabgrass, wild onion, and Johnson grass.

SURVEY IN BARNWELL COUNTY, S. C.

Barnwell County is located in the southwestern part of South Carolina. The tillage records for this county (Table XV) were taken near Barnwell, the county seat.

This is in the Coastal Plain area, and the predominating soil is a sandy loam with a clay subsoil. Some parts of the county are very sandy. The land is gently rolling, so that very little drainage is required. The bottom lands are drained by open ditches, which surround the fields. Some of the more rolling lands are drained by surface ditches and terraces.

About 60 per cent of the land has been cleared, and many of the stumps have not been removed. Many of the roads have been improved with sand and clay and are in good condition. Most of the land is owned by white men, but is largely worked by negro tenants. The average size of the farms visited is 193 acres, with 130 acres of improved land. The farm owners have good houses and appear prosperous.

TABLE XV.—*Tillage practice with cotton in Barnwell County, S. C., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 4 to 7 and 9 and 10 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.		Tillage after plowing and before planting.					Tillage after planting (all 1-horse implements).			Yield (pounds).
	Depth (inches).	Level.	Disk harrow.	Rows run with 1-horse 1-shovel plow.	Fertilizer distributor.	Bedded with turning plow.	All workings.	Sweep or scrape.	1-shovel plow.	All cultivations.	
1	2	3	4	5	6	7	8	9	10	11	12
1	5.5	1	1	2	3	4	4	1 to 6	....	6	800
2	6	1	1	2	3	4	4	1 to 6	1	6	700
3	8	1	1	2	3	4	4	1 to 6	3	6	1,400
4	7	1	1	2	3	4	4	1 to 6	3	6	800
5	6	1	1	2	3	4	4	1 to 6	2	6	1,000
6	6	1	....	1	2	3	3	1 to 7	....	7	800
7	5	1	....	1	2	3	3	1 to 7	2	7	700
8	5	1	1	2	3	4	4	1 to 6	....	6	750
9	6	1	....	1	2	3	3	1 to 7	....	7	7,000
10	6	1	....	1	2	3	3	1 to 6	....	6	....
11	6	1	....	1	2	3	3	1 to 6	2	6	1,000
12	6	1	....	1	2	3	3	1 to 6	....	6	900
13	6	1	....	1	2	3	3	1 to 7	....	7	1,000
14	6	1	....	1	2	3	3	1 to 5	....	5	750
15	7	1	1	2	3	4	4	1 to 7	....	7	1,000
16	7	1	1	2	3	4	4	2 to 7	[a]1	7	1,000
17	8	1	....	[b]1	2	3	3	1 to 6	1	6	1,000
18	6	1	....	1	2	3	3	1 to 6	3	6	750
19	6	1	1	2	3	4	4	1 to 7	....	7	750
20	5	1	....	1	2	3	3	1 to 5	....	5	900
21	8	1	[c]4	1	2	3	4	1 to 7	....	7	1,500
22	5	1	....	1	2	3	3	1 to 6	2 to 5	6	800
23	8	1	....	1	2	3	3	1 to 7	....	7	1,300
24	6	1	....	1	2	3	3	1 to 7	....	7	1,100
25	6	1	....	1	2	3	3	1 to 5	1	5	800
Farms using, per cent.	....	100	40	100	100	100	....	100	44	....	....
Average.	6	....	....	....	....	....	3.5	....	....	6.5	925

[a] Weeder. [b] Lister. [c] Spike-tooth harrow.

The principal crops grown are cotton, corn, and oats. No definite rotations are practiced, but frequently cotton is grown on the land two years and followed by corn one year. Cowpeas or peanuts are often planted between the corn rows at the last cultivation and harvested by hogs. Hardly enough corn is produced to feed the farm animals. When oats are sown they usually follow corn and are cut for hay or are fed without thrashing. Cowpeas are usually sown on the oat stubble and the vines cut for hay. Some watermelons and cantaloupes are grown for market, but very little fruit is grown. Few cattle are kept, and only enough hogs are raised to supply home demands. Almost the only source of farm income is cotton.

In preparing the land for cotton the old cotton or corn stalks are cut up during the winter with a stalk cutter or broken down by hand with a stick. The land is broken level in the early spring. Both 1-horse and 2-horse plows are used, about half the land being broken with each. If the land is rough after breaking, which is not often the case, a disk harrow is used. After plowing, the rows are laid off, usually without any further preparation, with a 1-horse shovel plow, the fertilizer is applied in this furrow with a distributor, and a bed is made on the fertilizer by throwing a furrow from each side with a turning plow. Cotton is then planted on this bed with a 1-horse planter, which tears down the bed and leaves the cotton only a few inches above level. The rows average 4 feet apart and 1 bushel of seed is planted per acre. After thinning, the stalks are left from 12 to 18 inches apart in the drill.

For cultivating the cotton 1-horse sweeps are employed. The first cultivation is given about two weeks after planting and a 1-horse 20-inch sweep is used, giving two furrows to each row. The cotton is then chopped to a stand. The next cultivation is with a 22-inch sweep, giving two furrows to the row and one furrow in the middle with a 1-horse 8-inch shovel. After this, 1-horse 22 and 24 inch sweeps are employed, giving two furrows to each row. In all six or seven cultivations are given. After chopping, the cotton is usually gone over with a hoe twice, to take out any weeds or extra cotton stalks. The hoe work is done mostly by women and children.

No cover crops are grown, and little stable manure is produced. Organic matter is supplied by plowing under crop residues and weeds. Commercial fertilizer is used extensively, the average application for cotton on the farms visited being 666 pounds per acre. About half this is applied before planting and the rest at the second or third cultivation. Nitrate of soda is often used as a top-dressing and applied at the second or third cultivation.

The principal varieties of cotton grown are Toole, King's Improved, and Cook's Improved.

The most troublesome and prevalent weeds are crab-grass, Bermuda grass, cocklebur, wild coffee, and nut-grass.

SURVEY IN PIKE COUNTY, GA.

Pike County is located in the west-central part of Georgia. The tillage records for this county, Table XVI, were taken near Zebulon. The soil of this area is a reddish-colored clay loam with a clay subsoil. The county is very rolling. Many surface ditches and terraces are required to carry off the surface water and prevent erosion.

This county has many rural improvements. Most of the roads have been improved with sand and clay and are kept in good condition. Good country schools are maintained. The average farm contains 144 acres, of which 96 acres are cultivated. Most of the farms are operated by their owners or by tenants who pay a cash rent. The actual work is performed largely by negro tenants or laborers. Most of the farms have good farmhouses, and the county is very attractive and apparently prosperous.

TABLE XVI.—*Tillage practices with cotton in Pike County, Ga., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 9 and 11 to 15 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.						Tillage after planting.						Yield (pounds).
					Bedded with—							1-horse.				
	Depth (inches).	Level.	Into beds.	Disk harrow.	Lister.	Turning plow.	Fertilizer distributor.	Spike-tooth harrow.	All workings.	Spike-toothed harrow.	Scooter and wing to bar off.	1-shovel plow.	Spring-tooth cultivator.	Scrape or sweep.	All cultivations.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	8	1	....	....	....	3	2	1	3	....	....	....	1	2 to 5	5	750
2	5	1	....	1	2	....	3	....	3	1	....	....	....	2 to 5	5	800
3	6	1	....	1	....	2	3	....	3	....	....	1	....	2 to 5	5	1,000
4	4	1	....	1	2	....	3	....	3	1	....	....	....	2 to 6	6	750
5	5	1	....	1	2	....	3	....	3	1,2	....	....	....	3 to 7	7	1,400
6	6	1	....	1	....	3	2	....	3	....	....	1	....	2 to 5	5	1,000
7	4	....	1	....	....	2	1	....	2	....	....	1	....	2 to 6	6	1,000
8	6	1	....	1	2	....	3	....	3	[a] 1	....	....	....	2 to 6	6	850
9	6	....	1	....	....	2	1	....	2	....	....	....	....	1 to 5	5	1,000
10	4	....	1	....	....	2	1	....	2	....	....	....	....	1 to 4	4	750
11	4½	....	1	....	....	2	1	....	2	....	....	....	1,2	3,4,5	5	750
12	5	1	....	1	2	....	3	....	3	....	....	....	1 to 4	5	5	1,000
13	5	1	....	....	1	2	3	....	3	....	....	....	1	2,3,4	4	750
14	4	....	1	....	....	2	1	....	2	....	1	....	....	2,3,4	4	1,000
15	8	1	....	....	1	3	2	4	4	....	....	....	1,2,3	4 to 7	7	1,200
16	6	1	....	1	[b] 2	4	3	5	5	....	....	....	1,2	3 to 6	6	1,000
17	10	1	....	....	[b] 2	4	3	1	4	....	1	....	....	2 to 6	6	1,000
18	8	1	....	1	2	4	3	....	4	....	1	....	....	2,3,4	4	1,000
19	6	1	....	....	[b] 2	....	3	1	3	1	2	....	....	3 to 6	6	1,200
20	4	1	....	1	2	4	3	....	4	....	....	....	....	1 to 6	6	750
21	6	1	....	1	2	....	3	....	3	....	1	....	....	2,3,4	4	750
22	8	1	....	1	2	....	3	....	3	....	1	....	....	2 to 6	6	800
23	10	1	....	1	[b] 2	....	3	....	3	....	....	1	....	2 to 6	6	900
24	5	1	....	1	2	4	3	....	4	....	....	....	1	2 to 5	5	500
25	8	1	....	1	[b] 2	4	3	....	4	....	....	....	1,2	3 to 6	6	700
Farms using, per cent	....	80	20	60	60	60	100	20	....	20	24	16	32	100	....	......
Average	6½	....	....	....	....	....	....	....	3	....	....	....	....	....	5.5	904

[a] One-horse, 5-shovel cultivator.

[b] Shovel and wings.

The principal crops grown are cotton, corn, and oats. No definite rotations are practiced. Cotton is grown usually on the best land. Cowpeas are sown on all stubble land and the vines cut for hay. Cowpeas also are planted between the corn rows and the vines plowed under after the peas are gathered. Some wheat is grown on a few farms. Sugar cane, peanuts, and sweet potatoes are grown for home use. This area is just on the border of the Georgia peach belt, and nearly every farmer grows a few peaches for home use. Very little fruit or truck is produced for market. Only enough cattle and hogs are kept for home use, and the farm income is almost entirely from cotton.

In the system of farming practiced cotton usually follows cotton or corn. In preparing the land the old stalks are broken up with a stalk cutter before the land is plowed. If the previous crop was corn, the land is broken in the fall. If the previous crop was cotton, early spring plowing is preferred.

Two-horse turning plows are generally used and the land is broken level. One-horse turning plows are used less frequently. Two-horse middle busters, or listers, are sometimes employed, which plow the land into beds.

Before planting, the land is harrowed with a disk harrow and thrown into beds with a turning plow or lister. The fertilizer is applied on this bed with a distributor and the cotton planted on the bed with a 1-horse planter. Sometimes the fertilizer is applied at the second or third cultivation. Cotton is planted at the rate of $1\frac{2}{5}$ bushels of seed per acre in rows that average $3\frac{1}{2}$ feet apart. After chopping is completed the stalks are left from 12 to 15 inches apart in the drill.

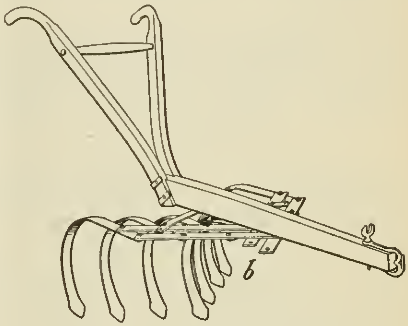

FIG. 17.—A 1-horse spring-tooth cultivator, extensively used for the tillage of cotton in Monroe County, Miss., and other parts of the cotton belt.

The cultural treatment after planting is very uniform. One-horse implements are used almost entirely. For the first cultivation a spike-tooth harrow or a spring-tooth 1-horse cultivator (fig. 17) is used. A few farmers use a 1-horse scrape, which pulls the earth away from the cotton, leaving a small ridge on which the cotton can be easily chopped to a stand.

For the second cultivation a 14-inch or a 16-inch scrape is employed, and three furrows are given each row. For the third cultivation about two weeks later, a 16-inch or an 18-inch scrape is used, putting three furrows to each row as before. For the later cultivations 22-inch and 24-inch scrapes are used and only two furrows are given each row. In all, five or six cultivations are given. Cotton is usually chopped to a stand with a hoe at the first or second cultivation and hoed again at the third or fourth cultivation to take out any weeds or extra stalks of cotton.

No cover crops are grown and little stable manure is produced. Commercial fertilizer, however, is used extensively, the average application for cotton on the farms surveyed being 416 pounds per acre.

The principal varieties of cotton grown are Cleveland Big Boll and Russell's Big Boll.

The most prevalent and troublesome weeds are crab-grass, coffee weed, cocklebur, and ragweed.

SURVEY IN TIFT COUNTY, GA.

Tift County is located in the south-central part of Georgia. The soil is sand or sandy loam and the subsoil clay. The land is gently rolling, so that little drainage is required except in the bottoms, where open ditches surround the fields. Most of the roads have been improved with sand and clay and are in fair condition except in dry weather, when the sand becomes deep. The farms are of medium size, averaging 160 acres, with only 93 acres cultivated. Most of the farms are operated by the owners with hired labor. The larger farms are worked by tenants under the supervision of the owners. The tillage records for Tift County are shown in Table XVII.

TABLE XVII.—*Tillage practices with cotton in Tift County, Ga., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 4 to 10 and 12 to 15 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.		Tillage after plowing and before planting.								Tillage after planting.					Yield (pounds).
			Harrow.				Bedded with—					1-horse.				
	Depth (inches).	Level.	Disk.	Spike-tooth.	Rows run with 1-horse 1-shovel plow.	Fertilizer distributor.	Turning plow.	1-horse 4-shovel cultivator.	1-horse spring-tooth cultivator.	All workings.	Spike-tooth harrow.	Spring-tooth cultivator.	Sweep or scrape.	1-shovel plow.	All workings.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	6	1	....	1	*a* 3	4	2	5	....	5	....	1,2	3 to 6	....	6	1,400
2	6	1	....	....	2	3	1,4	....	....	4	....	1	2 to 5	....	5	1,000
3	8	1	....	....	1	2	....	3	....	3	....	....	1 to 7	....	7	750
4	8	1	....	....	....	1	2	....	3	3	1	2	3,4,5	....	5	700
5	5	1	....	....	....	2	1,3	....	....	3	1	....	2,3,4	2	4	1,000
6	7	1	1	....	....	2	....	....	....	2	....	....	1 to 4	....	4	700
7	7	1	....	....	....	2	1,3	....	....	3	....	1	2,3,4	....	4	700
8	9	1	....	....	1	2	3	....	....	3	....	....	2 to 5	1	5	700
9	8	1	1	2	*a* 3	4	....	....	....	4	1	....	2 to 6	....	6	1,100
10	7	1	2	....	1	3	....	4	....	4	....	1,4	2,3,5,6	6	6	900
11	8	1	1	....	2	3	....	....	4	4	....	1	2 to 5	....	5	1,400
12	8	1	1	....	2	4	3	5	....	5	1	....	2 to 5	....	5	750
13	7	1	1	....	....	2	....	3	....	3	....	1	1 to 5	....	5	1,000
14	8	1	....	....	1	2	3	....	....	3	....	1	2,3,4	....	4	1,000
15	6	1	1	2	3	4	....	....	5	5	....	1,2	3,4,5	....	5	800
16	5	1	3	....	1	2	....	....	....	3	*b* 1	2	3,4,5	....	5	800
17	8	1	....	1	....	2	....	....	....	2	1	....	2,3,4	....	4	....
18	7	1	....	....	1	2	....	3	....	3	*c* 1,2	....	3 to 6	....	6	750
19	7	1	1	....	....	2	....	3	....	3	....	1	2 to 6	....	6	1,000
20	8	1	1	....	2	3	....	4	....	4	1,2	3,4	5 to 8	....	8	800
21	7	1	....	1	2	3	....	....	....	3	....	1,6	2 to 5	....	6	700
22	6	1	....	....	1	2	....	....	....	2	1	2,3	4,5,6	4,6	6	700
23	6	1	1	....	2	3	....	....	4	4	....	1,2,3	4,5	3,4	5	700
24	7	1	1	....	....	2	....	....	3	3	1,2	4	3,5,6	3	6	800
25	9	1	....	....	1	3	2,4	....	....	4	....	1,2	3 to 6	....	6	1,000
Farms using, per cent	....	100	48	20	68	100	36	32	20	....	40	76	100	24	....	....
Average	7	....	....	....	....	....	....	....	....	3.5	....	....	....	....	5.5	881

a Lister. *b* Disk harrow. *c* Weeder.

Because of the large area of land not cultivated, the cultivated fields are fenced to keep out cattle and hogs, which are allowed to run at large. Each farmer has a special brand by which his live stock is marked, so that they may be identified. Enough cattle and hogs are kept for home use, but few are sold.

The principal crops grown are cotton, corn, and oats. Some watermelons, cantaloupes, and cucumbers are produced for market, while sufficient sweet potatoes, sugar cane, peanuts, and truck crops are grown for home use. Very little fruit is produced. Cowpeas and peanuts are often grown between the corn rows and pastured by hogs and cattle. Cowpeas are sometimes sown on oat stubble and the vines cut for hay.

In preparing the land for cotton the old cotton or corn stalks are cut up with a stalk cutter during the winter or early spring. The land is broken level with a 2-horse turning plow and prepared for planting by harrowing with a disk or spike-tooth harrow. The rows are laid off with a 1-horse shovel plow at an average distance of 4 feet apart. Fertilizer is applied in these furrows with a distributor and a bed made on the fertilizer with a 1-horse 4-shovel cultivator equipped with turning shovels. Cotton is then planted on this bed with a 1-horse planter.

From 2 to 3 pecks of seed are planted per acre. The superfluous plants are subsequently chopped out, leaving the cotton stalks from 15 to 20 inches apart in the drill.

After planting, the first cultivation is given with a spike-tooth harrow or with a 1-horse spring-tooth cultivator. This cultivation is just after the cotton comes up. All later cultivations are given with 1-horse scrapes or sweeps. At first, a 14-inch heel scrape and scooter is used and the entire middle plowed out, which requires three furrows. The cotton is then chopped to a stand. At the next cultivation a 16-inch or an 18-inch scrape is used and only two furrows are given each row. The entire middle is plowed out at every other cultivation. This is usually done with a sweep or scrape, but some farmers use a 1-horse shovel plow instead. Later 22-inch and 24-inch scrapes are used, and two furrows are given each row. During the season five or six cultivations are given and the crop is gone over twice with a hoe. Negro women and children do most of the hoe work.

No cover crops are grown, and since the cattle run at large little stable manure is saved. What manure is saved is applied to watermelons and cantaloupes. Commercial fertilizer is used by every farmer. The average application per acre for cotton is 342 pounds. This is applied in the drill before planting.

The principal varieties of cotton grown are Summerhour, Half-and-Half, Cook's Improved, and Toole.

The most prevalent and troublesome weeds are crab-grass, Bermuda grass, cocklebur, and coffee weed.

SURVEY IN GILES COUNTY, TENN.

Giles County is located in the south-central part of Tennessee. The topography of this county is very irregular. Parts of it are extremely rolling and rough, while the bottoms and lowlands consist of gentle slopes and low, rolling hills. The soil of the upland is a clay loam with a clay subsoil, but the bottom land is a silty loam. The latter lands are drained by open ditches and are exceptionally fertile. The tillage records for this county are shown in Table XVIII.

TABLE XVIII.—*Tillage practices with cotton in Giles County, Tenn., showing depths of plowing, implements used in order of their use, number of times each is used, and normal acre yields.*

[In columns 4 to 11 and 13 to 18 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.		Tillage after plowing and before planting.									Tillage after planting.							Yield (pounds).
	Depth (inches).	Into beds.	Harrow.		Rows run with 1-horse 1-shovel plow.	Fertilizer distributor.	Bedded with—		Roller.	Log drag.	All workings.	1-horse 1-shovel plow.	Cultivator.				1-horse sweep.	All cultivations.	
													1-horse.			2-horse 4-shovel.			
			Disk.	Spike-tooth.			1-horse sweep.	Turning plow.					Harrow tooth.	2-shovel.	2-shovel with sweeps.				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	5	1	...	2	...	...	1	...	...	...	2	...	1	2, 3	4	...	...	4	1,000
2	5	1	...	3	1	...	...	2	...	...	3	...	1	...	2 to 5	...	6	6	1,000
3	5	1	...	...	2	3	...	1	...	...	3	...	1	2 to 5	...	...	...	5	800
4	5	1	...	1, 4	2	...	...	3	...	...	4	...	1	2	3, 4. 5	...	...	5	500
5	7	1	...	1	a 4	3	...	2	...	...	4	1	2 to 6	...	...	...	...	6	1,500
6	5	1	1	...	2	...	...	3	...	...	3	1	2	5	...	3, 4	...	5	1,000
7	7	1	...	1, 3	...	...	...	2	...	...	3	...	1	2 to 5	...	...	...	5	800
8	8	1	1	...	2	3	...	4	...	...	4	...	b 1	...	...	2, 3, 4	5	5	1,200
9	5	1	1	2	...	...	3	...	...	...	3	1	c 2	...	...	3, 4, 5	...	5	700
10	7	1	...	1	...	...	...	3	2	4	4	...	1, 2	6	3, 4, 5	...	...	6	800
11	4	1	...	1	...	...	...	2	...	3	3	...	1, 2	3 to 6	...	...	...	6	600
12	5	1	2	1, 4	...	...	...	3	...	...	4	...	1, 2	3, 4	...	...	5, 6	6	800
13	5	1	1	3	...	...	...	2	...	...	3	...	1	...	...	2 to 5	6	6	800
14	7	1	1	3	...	...	...	2	...	...	3	...	1, d 2	3	...	4, 5	6	6	800
15	5	1	1	d 4	2	...	...	3	...	...	4	...	1, 2	3, 4	...	5, 6, 7	...	7	800
16	5	1	...	2	...	...	...	1	...	...	2	...	1	2 to 5	...	...	...	5	800
17	4	1	...	1, 4	2	...	...	3	...	...	4	...	1	3	4, 5	...	...	5	1,000
18	4	1	...	1, 3	...	...	...	2	...	...	3	...	1	2, 3, 4	...	...	...	4	1,000
19	4	1	...	3	1	...	...	2	...	...	3	...	1	2	...	3, 4, 5	...	5	800
20	6	1	1	3	...	...	2	...	...	...	3	...	1, 2	3, 4	...	...	5	5	500
21	6	1	...	1, 3	...	...	...	2	...	...	3	...	1	2, 3, 4	...	...	5	5	800
22	5	1	2	4	...	...	...	e 3	1	...	4	...	1, 2	3, 4, 5	...	...	6	6	700
23	5	1	1	...	...	...	3	...	2	...	3	...	1, 2, 3	4, 5, 6	...	...	...	6	800
24	6	1	...	1, 4	2	...	...	3	...	...	4	1	2	3	4, 5, 6	...	...	6	1,200
25	4	1	1	...	...	...	2	...	3	...	3	1	2	...	...	3, f 4	5	5	800
Farms using, per cent	...	100	44	80	40	12	20	80	16	8	...	20	100	76	24	32	36	...	...
Average	5½	...	...	...	...	...	...	...	...	...	3½	...	...	...	...	...	...	5½	860

a One-horse 2-shovel plow. b Spike-tooth harrow. c Roller. d Spring-tooth harrow. e Lister. f With sweeps.

The county is fairly well improved. Many of the roads have been macadamized, and good country schools are maintained. The average size of the farms surveyed is 221 acres, with 136 acres cultivated. The farms are owned by white men, who live on them, but most of the work is done by tenants under the supervision of the landlord. Most farmers have comfortable houses and good outbuildings and appear to be prospering. This is especially true of the bottom-land farmers.

The principal crops grown are corn, oats, wheat, hay, bluegrass for pasture, and cotton. No definite rotations are practiced, but the crops are changed from field to field without following any fixed order. Very little cotton is grown in the northern part of the county, but it is produced more extensively south of Pulaski. Corn is planted on the more productive bottom lands and cotton on the uplands. Many of the hillsides are in bluegrass pasture or clover. Oats are grown only for feed, and very little wheat is produced. Most of the corn is fed on the farm. Some hay is baled and sold. Cotton is the principal crop sold. Many sheep and goats and a few beef cattle and hogs are raised for market. Extra brood mares are kept on the farms, and nearly every farmer raises mule colts for market. The farm income is derived principally from the sale of live stock and cotton.

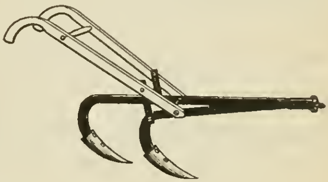

FIG. 18.—A 1-horse 2-shovel cultivator used for the tillage of cotton in Giles County, Tenn., and other sections of the cotton belt. Sometimes small sweeps are attached instead of shovels.

In preparing a seed bed for cotton, if the previous crop was cotton or corn the old stalks are sometimes broken up with a stalk cutter or disk harrow. Early in the spring the land is broken level with a 2-horse plow. The land is harrowed with a disk or spike-tooth harrow, the rows laid off with a 1-horse shovel plow, and a bed made on this row with a turning plow or with a 1-horse sweep. Sometimes the bed is made without laying off the row. These beds are often harrowed with a spike-tooth harrow, which smooths off the tops and leaves them almost level with the surface. Cotton is planted on this bed with a 1-horse planter at the rate of 5 pecks of seed per acre. The rows average 3 feet apart. After chopping, the stalks are left from 12 to 15 inches in the drill.

For cultivating after planting, 1-horse implements are principally used. Just after the cotton is up, the first cultivation is given with a 1-horse harrow-tooth cultivator, and generally this implement is used for the second cultivation also. Then the cotton is chopped to a stand. After this, most of the cultivating is done with a 1-horse 2-shovel cultivator known as a "double shovel" (fig. 18). This cultivator is equipped with broad shovels or sweeps. Two furrows are required for each row with this tool. A few farmers use a 2-horse 4-shovel cultivator, while a few use a 1-horse sweep. A total of five or six cultivations is given during the season. At the third or fourth cultivation the cotton is gone over with a hoe a second time, to chop out any weeds and extra stalks of cotton.

Only a very few farmers use commercial fertilizer, and these only in an experimental way. What stable manure is used is applied broadcast on the least productive spots in a field. No cover crops are grown, but organic matter is supplied by hay and pasture crops.

The principal varieties of cotton grown are King's Improved, Cook's Improved, and mixed varieties.

The most prevalent and troublesome weeds in this county are crab-grass, careless weed, nut-grass, cocklebur, smartweed, morning-glory, and Johnson grass.

SURVEY IN BULLOCH COUNTY, GA.

Bulloch County is located in the eastern part of Georgia in the Coastal Plain area. The tillage records for this county (Table XIX) were taken near Statesboro. The soil here is a sandy loam with a clay subsoil. The land is level or gently rolling, and little artificial drainage is required. The bottoms are drained by means of open ditches. None of the land is tiled. Many of the roads have been macadamized or improved with sand and clay and are in good condition. The average-sized farm studied is 178 acres, with only 85 acres cultivated. Most of the farms are supervised by the owners and worked with hired or tenant labor.

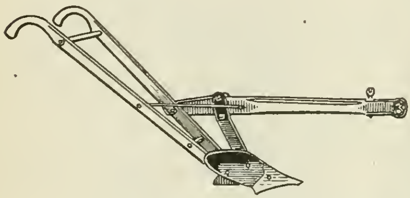

FIG. 19.—A 1-horse turning plow used in many areas when preparing land for cotton; also used in many sections for cultivating cotton.

No definite rotations are practiced. The principal crops grown are cotton, corn, watermelons, oats, and peanuts. Many farmers grow watermelons for market. Sweet potatoes, sorghum cane, and truck crops are grown for home use. Cowpeas and peanuts are often grown between the corn rows and harvested by hogs. Cowpeas are sometimes sown on oat stubble and the vines cut for hay. Many of the oats are cut for hay while the grain is in the dough stage. Enough cattle are kept for home use, and some hogs are raised for market. The principal source of farm income is from cotton and watermelons.

In preparing a seed bed for cotton the plowing is done in the early spring after the old cotton or corn stalks have been cut up with a stalk cutter during the winter months.

The land is broken level with a 1-horse or 2-horse plow. The soil is very deep, and the average depth of breaking is 6 to 8 inches. After plowing, a spike-tooth or disk harrow is sometimes used, but this is not often necessary. A broad furrow is then plowed out for the row. This is often done with a 1-horse turning plow (fig. 19), using two furrows and throwing the soil to each side, and then often an 8-inch shovel plow is run in the bottom of this furrow. Sometimes a 2-horse middle buster, or lister, is used to make this furrow. Fertilizer is applied in the bottom of the furrow with a distributor and the land rebedded on the fertilizer with a 1-horse cultivator equipped with turning shovels. Cotton is planted on this bed with a 1-horse planter. The average width of row is 4 feet, and 3 pecks of seed are planted per acre. After thinning, the stalks are left from 15 to 20 inches apart in the drill.

TABLE XIX.—*Tillage practices with cotton in Bulloch County, Ga., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 10 and 12 to 19 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.							Tillage after planting (all 1-horse implements).									Yield (pounds).
				Bedded with—							Cultivator.									
	Depth (inches).	Level.	Into beds.	Lister.	Turning plow.	1-horse cultivator with turning shovels.	Disk harrow.	Rows run with 1-horse 1-shovel plow.	Fertilizer distributor.	All workings.	Harrow tooth.	3-shovel.	3-shovel with sweeps.	5-shovel.	Spring-tooth.	1-shovel plow.	Sweep or scrape.	Turning plow.	All cultivations.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	9	1	...	...	1	4	...	2	3	4	...	...	...	1,3	...	2	3 to 6	...	6	1,300
2	9	1	...	1	...	3	...	...	2	3	...	1,2	3	...	...	...	4,5	...	5	750
3	5	1	...	...	1	4	...	2	3	4	...	...	...	1,2	...	...	3,4,5	...	5	600
4	8	1	...	...	...	4	1	2	3	4	1	...	2 to 6	...	...	...	...	...	6	1,350
5	5	1	...	...	1	4	...	2	3	4	...	...	...	...	...	...	2 to 6	1	6	750
6	9	1	...	1	...	3	...	...	2	3	1	...	3,4,5	...	...	...	2,6,7	...	7	600
7	7	1	...	...	3	...	...	1	2	3	...	...	...	...	...	2	1 to 5	...	5	500
8	9	1	...	...	1,4	...	...	2	3	4	...	1,3	...	...	...	5	2,4,5,6	...	6	900
9	5	1	...	...	...	3	...	1	2	3	...	...	...	...	...	5	1 to 6	...	6	650
10	6	1	...	...	3	...	...	1	2	3	1	...	...	...	...	...	2 to 5	...	5	600
11	6	1	...	...	...	4	1	2	3	4	...	1	2 to 5	...	...	...	...	...	5	800
12	8	1	...	1	3	...	...	...	2	3	...	...	1 to 5	...	...	...	...	...	5	1,000
13	5	1	...	...	...	3	...	1	2	3	1	...	...	...	...	...	2 to 6	...	6	800
14	8	1	...	...	2	4	1	...	3	4	1	...	...	...	...	...	2 to 7	...	7	1,200
15	9	1	...	1	...	4	*a* 2	...	3	4	1	...	...	...	2	...	3 to 6	...	6	900
16	8	1	...	...	1	4	...	3	2	4	...	1	...	...	...	...	2 to 5	...	5	700
17	9	1	...	...	...	4	*a* 1	2	3	4	...	1	...	...	...	3,5	2,4,6	...	6	700
18	5	1	...	...	4	...	2	1	3	4	1	...	3,4,5	...	...	...	2	...	5	1,000
19	6	1	...	...	...	3	...	1	2	3	1	...	3	...	...	2	2,4,5	...	5	600
20	5	1	...	...	3	...	...	1	2	3	...	3	...	...	...	1,2	4,5,6	...	6	1,100
21	5	...	1	...	3	...	...	1	2	3	...	*b* 1	2	...	...	...	3,4,5	...	5	750
22	6	1	...	...	...	3	...	1	2	3	1	...	...	3	...	...	2 to 6	...	6	700
23	9	1	...	1	...	3	...	...	2	3	...	2,3	...	...	1	...	4 to 7	...	7	700
24	8	1	...	...	...	3	...	1	2	3	...	1,2	...	...	...	...	3,4	...	4	700
25	4	1	...	...	1,4	...	...	2	3	4	...	...	...	...	...	...	(*c*)	3,6	8	750
Farms using, per cent.	...	96	4	20	52	68	24	76	100	...	36	36	32	12	8	28	88	8	...	...
Average.	7	...	...	...	...	...	...	...	...	3.5	...	...	...	...	...	...	...	...	5.5	816

a Spike-tooth harrow. *b* One-horse 2-shovel plow. *c* Cultivations 1, 2, 4, 5, 7, and 8.

The cultivating after planting is all done with 1-horse implements. The first cultivation is given with a 1-horse harrow-tooth cultivator or a 1-horse 3-shovel cultivator. The cotton is then chopped to a stand. After chopping a 1-horse sweep or scrape is employed. Some farmers use a 1-horse 3-shovel cultivator equipped with small sweeps instead of shovels. Where the 1-horse sweep or scrape is employed, 14-inch or 16-inch lengths are used at first and a size larger for each succeeding cultivation. For the last cultivation a 22-inch or 24-inch sweep is used. Two furrows are given for each cultivation, and at every other cultivation an extra furrow is given so as to plow out the entire middle. The 1-horse turning plow, the 1-horse 1-shovel plow, the 1-horse harrow-tooth cultivator, and the 1-horse 5-shovel cultivator are used less extensively. During the season five or six cultivations are given.

At the third or fourth cultivation the cotton is again gone over with a hoe, to take out any extra stalks or weeds. Very little stable manure is produced, but commercial fertilizer is used extensively. The average quantity applied per acre for cotton is 506 pounds. No cover crops are grown, and organic matter is supplied only by crop residues and by weeds and grass which are plowed under.

The principal varieties of cotton grown are Toole, Sea Island, and Mortgage Lifter.

The most prevalent and troublesome weeds are crab-grass, wild coffee, cocklebur, Bermuda grass, and pigweed.

SURVEY IN ST. FRANCIS COUNTY, ARK.

St. Francis County is located in the east-central part of Arkansas. The tillage records for this county (Table XX) were taken near Forrest City.

The topography and soils are very irregular. In parts of the county extensive bottom lands are found, which are level and very fertile. Other parts of the county are extremely hilly and rolling and not so productive. The predominating soil type is a silt loam grading into a heavier subsoil.

The bottom lands are drained by means of deep open ditches which surround the fields. The hill farms are drained by numerous terraces and surface ditches, which are necessary to control the surface water and prevent erosion.

The hill farms are of medium size and are worked by the owners or by tenants who supervise their own work. The bottom-land farms, however, are larger and are adjusted mostly on a commercial basis. The work is all done by negro tenants, but supervised by the owner or a hired manager.

The principal crops grown are cotton, corn, oats, and cowpeas. No definite rotations are practiced. Cotton is the principal crop and is grown on the most productive land. Only a few oats are grown, and these are often cut for hay while the grain is in the dough stage. Cowpeas are usually sown on the stubble land and the vines cut for hay. Cowpeas and peanuts are also planted between the corn rows and harvested by hogs or cattle. Some alfalfa is grown on the bottom lands. Watermelons and truck crops are grown for home use on nearly every farm. Little fruit is produced. Many farmers grow Bermuda grass for pasture. Enough cattle and hogs for home use are kept on every farm and a few are sold, but the principal source of farm income is cotton.

TABLE XX.—*Tillage practices with cotton in St. Francis County, Ark., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5, 6, and 8 to 12 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm. No.	Plowing.			Tillage after plowing and before planting.			Tillage after planting.						Yield (pounds).
							1-horse.			Cultivator.			
	Depth (inches).	Level.	Into beds.	Spike-tooth harrow.	Bedded with turning plow.	All workings.	Harrow-tooth cultivator or side harrow.	2-shovel cultivator with sweeps.	Sweep or scrape.	2-horse 2-shovel with sweeps.	1-horse 3-shovel.	All workings.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	3	....	1	1	......	1	a 1, 2	5	3, 4	....	....	5	600
2	4	....	1	1	......	1	....	4	1, 2, 3	....	5	5	900
3	4	....	1	1, 2	b 3	3	1	....	3, 7	2, 4, 5, 6	....	7	900
4	6	1	....	1, 4	c 2, 3	4	....	4	1, 2, 3	....	....	4	750
5	4	....	1	1	......	1	1	....	2 to 5	....	....	5	750
6	3	....	1	1	......	1	1	....	2, 3, 4	....	....	4	650
7	4	....	1	1, 2	......	2	1, 5	d 4	2, 3, 6, 7	....	....	7	750
8	4	....	1	2	1	2	....	(e)	3, 4	....	....	4	750
9	5	....	1	1, 2	......	2	....	....	1 to 5	....	....	5	750
10	4	....	1	2	1	2	a 1, 2, 4	3, 5	....	....	....	5	750
11	3	....	1	1, 2	......	2	1	....	2 to 5	....	....	5	600
12	6	....	1	2	1	2	1, 6	4, 5	2	....	3	6	750
13	4	....	1	2	1	2	1, 5	3	2, 4	....	....	5	......
14	4	....	1	1	......	1	1, 2, 5	3, 6	4	....	....	6	750
15	3	....	1	1	......	1	2	4, 5	1, 3, 6	....	....	6	700
16	6	....	1	2	1	2	....	....	1 to 5	....	....	5	700
17	6	....	1	1	......	1	1	3, 4, 5	2, 6	....	....	6	1,200
18	3	....	1	2	1	2	1, 3, 5	....	2, 4	....	....	5	750
19	3	....	1	2	1	2	1	4	2, 3	....	5	5	750
20	5	....	1	1	......	1	1, 2	3	4, 5, 6	....	....	6	900
21	3	....	1	......	1	1	....	....	1 to 5	....	....	5	750
22	3	....	1	1	......	1	1	....	4, 5	2, 3	....	5	700
23	4	....	1	1	......	1	1, 4	....	2, 3, 5	....	....	5	800
24	6	....	1	1	......	1	1	3, 4, 5	2, 6	....	....	6	750
25	4	....	1	2	1	2	1	2	3, 4	....	....	4	750
Farms using, per cent	....	4	96	96	44	.....	76	56	96	8	12	....	.....
Average	4	....	....	......	......	1.5	....	....	....	....	....	5	767

a Spike-tooth harrow.
b Plank drag.
c Shovel plow.
d Turning plow.
e Cultivations 1, 2, and 3, with turning plow.

The general methods of preparing a seed bed for cotton are very uniform. During the winter the old cotton or corn stalks are cut with a stalk cutter and in the early spring the land is plowed with a 1-horse or 2-horse turning plow. Most often 1-horse plows are used. As broken, the land is thrown into beds the width apart the cotton rows are to be. Before planting, these beds are harrowed once or twice with a spike-tooth harrow, which brings the bed down almost level. If the land is rough or not in good condition, it is often rebedded with a turning plow and then harrowed with a spike-tooth harrow just before planting. Cotton is planted on this small bed with a 1-horse planter. The rows average $3\frac{1}{2}$ feet apart and $1\frac{2}{5}$ bushels of seed is planted per acre. After thinning, the stalks are left from 12 to 15 inches apart in the drill.

For cultivating after planting, 1-horse implements are largely employed.

About 10 days after planting, the first cultivation is given with a 1-horse harrow-tooth cultivator known as a "side harrow." This implement is sometimes used for the second cultivation. After the first or second cultivation the cotton is chopped to a stand. The following cultivations are given with a 1-horse sweep or scrape. Small 12-inch or 14-inch scrapes are used at first, and the size increased with each cultivation up to 20 or 22 inches. Many farmers use a 1-horse 2-shovel cultivator equipped with solid sweeps instead of shovels. A few farmers use a 1-horse 3-shovel cultivator (fig. 20) and a 2-horse 2-shovel cultivator equipped with broad sweeps instead of shovels. At the third or fourth cultivation the cotton is again gone over with a hoe and any extra stalks or weeds are chopped out. In all, five or six cultivations are given. In cultivating, the soil is gradually worked toward the cotton, thus leaving the row on a slight ridge at the last cultivation.

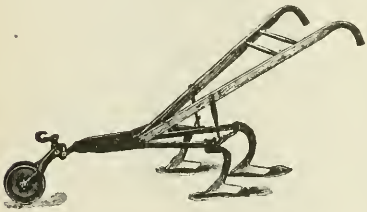

FIG. 20.—A 1-horse 3-shovel cultivator equipped with small sweeps instead of shovels, used for the tillage of cotton in St. Francis County, Ark., and other parts of the cotton belt.

No cover crops are grown and no commercial fertilizer is used. What stable manure is produced is applied to the truck crops and on the poorer spots over the fields.

There are numerous varieties of cotton grown in this county. Some of the most popular are King's Improved, Russell's Big Boll, and Simpkins' Prolific.

The most prevalent and troublesome weeds are crab-grass, Bermuda grass, cocklebur, morning-glory, Johnson grass, and nut-grass.

SURVEY IN ELLIS COUNTY, TEX.

Ellis County is located in the northeastern part of Texas. The tillage records for this county (Table XXI) were taken near Waxahachie. This is one of the most prosperous farming counties in the State. The soils are exceptionally fertile and the seasons are usually favorable.

TABLE XXI.—*Tillage practices with cotton in Ellis County, Tex., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5, 6, 7, 9, and 10 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.				Tillage after planting.		Yield (pounds).
	Depth (inches).	Level.	Into beds.	Spike-tooth harrow.	2-horse. 4-shovel cultivator with sweeps.	2-horse. 1-row lister planter.	All workings.	2-horse 4-shovel cultivator with sweeps.	All cultivations.	
1	2	3	4	5	6	7	8	9	10	11
1	4	....	1	....	....	1	1	1 to 5	5	750
2	4½	....	1	2	1	3	3	1 to 6	6	750
3	3	....	1	....	....	1	1	1 to 4	4	750
4	4	....	1	1	....	2	2	1 to 4	4	750
5	1	....	1	....	....	1	1	1 to 4	4	750
6	3	....	1	....	....	1	1	1 to 4	4	750
7	4	....	1	....	....	1	1	1 to 5	5	700
8	4	....	1	....	....	1	1	1 to 6	6	500
9	3½	....	1	1	....	2	2	1 to 4	4	600
10	4	....	1	1	....	2	2	1 to 5	5	750
11	4	....	1	1	....	2	2	1 to 7	7	600
12	4	....	1	1	....	2	2	1 to 5	5	700
13	6	....	1	1	....	2	2	1 to 4	4	500
14	4	....	1	1	....	2	2	1 to 4	4	600
15	4	....	1	....	....	1	1	1 to 4	4	750
16	4	....	1	1	....	2	2	1 to 5	5	650
17	5	....	1	1	....	2	2	1 to 5	5	750
18	4	1	....	1	[a] 2	3	3	1 to 4	4	750
19	3	....	1	1	....	2	2	1 to 6	6	750
20	3½	....	1	....	....	[b] 1	1	([c])	4	750
21	3	....	1	1	....	2	2	1 to 5	5	750
22	3	....	1	1	....	2	2	1 to 4	4	500
23	6	....	1	1	....	2	2	1 to 5	5	800
24	3	....	1	1	....	2	2	1 to 6	6	500
25	3	....	1	1	....	2	2	1 to 6	6	700
Farms using, per cent	....	4	96	68	4	100	....	100	....	....
Average	4	....	....	....	....	....	2	....	5	684

[a] One-horse sweep.
[b] Three-horse 2-row lister planter.
[c] Cultivations 1 to 4, with 4-horse 2-row cultivator.

Many rural improvements have been made, and the country is very attractive. Most of the roads have been macadamized and are kept in excellent condition. Good schools and churches are maintained. The farmers have exceptionally good houses and good barns and outbuildings.

The rural population is mostly native white Americans. In the eastern part of the county many Germans and Bohemians have settled. Many negroes are found around the towns. Most of the farms are of medium size and are worked by the owners or by tenants who supervise their own work.

Improved labor-saving machinery is largely employed, which enables one man to work 40 to 50 acres of cotton with the exception of chopping to a stand and harvesting the crop. For this extra work negro labor is secured in the cities; men, women, and children come out in parties and live in tents while doing this work.

Through the central part of the county runs a broad belt of Houston black-clay soil. This is a prairie region, with broad, gently rolling land that requires very little drainage. In this belt 80 per cent of the cultivated land is in cotton annually. Some corn and oats are grown for feed, but no rotations are practiced. In the western part of the county some wheat is produced, and in the eastern section on the sandy soils peaches and truck are extensively grown; but in both areas cotton is the principal money crop. Few cattle and hogs are kept, and few farm products other than cotton are sold.

In preparing the land for cotton heavy teams and large implements are used. During the late winter or early spring the land is plowed with a 4-horse middle buster, or lister. The old cotton stalks are plowed up and the land thrown into beds the width apart the cotton rows are to be. With this implement only one furrow is required for each row. If the stalks are rank, they are cut up with a stalk cutter before plowing or are raked up after plowing and burned. Before planting, these beds are harrowed once with a spike-tooth harrow.

Cotton is planted with a 2-horse 1-row lister planter. This planter has a broad shovel which tears down the bed and leaves the cotton planted almost level with the surface. The cotton rows average 3 feet apart, and 2 to 3 pecks of seed are planted per acre. After thinning, the stalks are left from 12 to 15 inches apart in the drill.

After planting, all the cultivating is done with a 2-horse 1-row 4-shovel cultivator equipped with buzzard-wing sweeps instead of shovels. For the first cultivation, which is given ten days or two weeks after planting, small 6-inch or 8-inch sweeps are used next to the cotton and 10-inch or 12-inch sweeps on the outside. The cotton is chopped to a stand after the first cultivation and gone over with a hoe once or twice later in the season, to chop out any extra stalks and weeds. For later cultivations 12, 14, and 16 inch sweeps are used on the same cultivator. During the season four or five cultivations are given, and level cultivation is always practiced.

The black soils are very fertile and no commercial fertilizer is used. Little stable manure is produced, and this is applied broadcast to the poorer spots in the fields.

The principal varieties of cotton grown are Mebane and Rowden.

The most prevalent and troublesome weeds of this county are careless weed, hurrah grass, cocklebur, morning-glory, and Johnson grass.

SURVEY IN CHAMBERS COUNTY, ALA.

Chambers County is located in the east-central part of Alabama. The tillage records for this county (Table XXII) were taken near Lafayette. The soil is principally a clay loam with a clay subsoil, but the bottoms and lowlands are sandy loam. This county is on the border line between the Piedmont and Coastal Plain areas and there is a combination of gently sloping plains and steep hills. The steeper lands are drained by numerous terraces and surface ditches. The organic content of the soil is very low, and this extensive drainage system is necessary to prevent erosion.

The landowners of the county are very prosperous and have good country homes. The farms are large and are mostly worked by negro tenants and supervised by the owner or by a white tenant who rents the entire farm from the owner for a stated quantity of cotton or amount of money, and then subrents to negro tenants on a share basis.

TABLE XXII.—*Tillage practices with cotton in Chambers County, Ala., showing depth of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 9 and 11 to 15 the figures show the order in which the implement was used on the several farms: as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.						Tillage after planting.						Yield (pounds).
	Depth (inches).	Level.	Into beds.	Lister.	1-horse 1-shovel plow.	Fertilizer distributor.	Bedded with turning plow.	1-horse spring-tooth cultivator.	All workings.	Spike-tooth harrow.	Shovel and left wing to bar off.	1-horse. Spring-tooth cultivator.	1-horse. Turning plow.	1-horse. Sweep or scrape.	All cultivations.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	8	1		1		2	3	4	4		1			2 to 6	6	750
2	4		1			1	2		2		1			2 to 6	6	750
3	7	1		1		2			2			2		1 to 7	7	750
4	6	1			1,3	2			3		1			2,3,4	4	500
5	5	1		1		2	3		3	1			3	2,4,5,6	6	750
6	4	1		1		2	3		3		1			2 to 5	5	600
7	6	1		2		3	4	a 1	4		1			2 to 6	6	600
8	4	1			1	2	3		3			1		2 to 5	5	500
9	8	1		1		3	2		3				1	2 to 5	5	800
10	5	1			1	2	3		3					1 to 6	6	800
11	6	1		1		3		b 2	3	1				2 to 6	6	750
12	5	1		1		2	3		3			1		2 to 5	5	500
13	5		1			1	2	b 3	3	1		2		3 to 6	6	750
14	4	1		1		2	3		3		1			2 to 6	6	600
15	5½	1		1		2	3	4	4	1	3	2,8		4–7,9	9	700
16	4	1		1		2	3		3			1		2 to 5	5	600
17	4		1			1	2		2		1			2 to 6	6	800
18	9		1			1	2		2			1	2	3,4,5	5	600
19	6	1		1		2	3	4	4			1		2,3,4	4	750
20	5	1			1	2	3		3		1			2 to 6	6	600
21	4		1		1	2	3		3		1			2 to 5	5	700
22	4		1	1		2	3	4	4			1		2 to 6	6	750
23	6	1		1		2	3		3		1			2 to 5	5	700
24	4		1		1	2	3		3			1		2 to 5	5	700
25	7	1		1		2		3	3		1			2 to 5	5	600
Farms using, per cent		72	18	60	24	100	84	32		16	48	40	12	100		
Average	5½								3						5½	676

a Spike-tooth harrow.

b Spring-tooth harrow.

The principal crops grown are cotton, corn, and oats. No definite rotations are practiced. About two-thirds of the land is in cotton annually. Hardly enough corn is produced for home use. What oats are produced are fed on the farm and often without thrashing. Cowpeas, peanuts, sugar cane, sweet potatoes, fruit, and truck crops are grown for home use. Enough cattle and hogs are kept for home use, but little is sold from the farm except cotton.

In preparing a seed bed for cotton there are two general methods employed. By the first method, which is largely employed, the old cotton or corn stalks are plowed out with a 2-horse middle buster, the fertilizer applied in this furrow, and a bed made on the fertilizer with a 1-horse turning plow.

Sometimes the land is broken level, the rows laid off with a middle buster or broad shovel, the fertilizer applied in this furrow with a distributor, and a bed made on the fertilizer with a 1-horse turning plow. Four furrows are required for each bed. This plowing is done in the early spring. If the old cotton or corn stalks are rank they are sometimes cut up with a stalk cutter before breaking the land.

At planting time, if the land is rough these beds are harrowed with a spring-tooth harrow. Cotton is planted on the bed with a 1-horse 1-row planter. The rows average $3\frac{1}{2}$ feet apart, and $1\frac{1}{4}$ bushels of seed are planted per acre. After thinning, the stalks are left from 12 to 15 inches apart in the drill.

For cultivating after planting, 1-horse implements are generally employed. Just after the cotton comes up, often a spike-tooth harrow is used, and later a 1-horse shovel plow with a sweep attached. This implement throws the soil away from the cotton and leaves the plants on a small ridge, giving the same effect as barring off with a turning plow. Sometimes a turning plow is used for this cultivation. After the first cultivation the cotton is chopped to a stand. For later cultivations the 1-horse sweep or scrape is used entirely. At first 16-inch or 18-inch sweeps are used, and three furrows are required for each row. For later cultivations longer sweeps are used. During the season five or six cultivations are given and the cotton is slightly ridged up during the cultivating. At the third or fourth cultivation any extra cotton stalks or weeds are chopped out with a hoe. No cover crops are grown and little stable manure is produced. Commercial fertilizer is used on every farm. The average application per acre for cotton is 312 pounds.

The principal varieties of cotton grown are Christopher, Russell's Big Boll, King's Improved, and Cook's Improved.

The most prevalent and troublesome weeds are crab-grass, coffee weed, cocklebur, Johnson grass, Bermuda grass, and nut-grass.

SURVEY IN JOHNSTON COUNTY, OKLA.

Johnston County is located in the south-central part of Oklahoma and is a part of the area which comprised the Indian Territory. The tillage records for this area (Table XXIII) were taken near Tishomingo.

The prevailing soil is a sand or clay loam with a heavier loam subsoil. The topography of this area is irregular. Some parts are very rolling or hilly and are drained by surface ditches. In other parts of the county there are broad, gently rolling prairie areas which require no drainage.

TABLE XXIII.—*Tillage practices with cotton in Johnston County, Okla., showing depth of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 8 and 10 to 14 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.					Tillage after planting.						Yield (pounds).
				Harrow.						Cultivation.					
											2-horse 4-shovel with—				
	Depth (inches).	Level.	Into beds.	Spike-tooth.	Disk.	1-horse sweep.	2-horse 1-row lister planter.	All workings.	Spike-tooth harrow.	2-horse lister.	Shovels.	Sweeps.	1-horse 2-shovel.	All cultivations.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	4	1	....	1	....	2	....	2	......	....	....	1, 3, 4	2	4	600
2	4	....	1	1, 2	....	....	....	2	1	....	....	2 to 6	....	6	800
3	3	....	1	1	....	....	2	2	......	1	2	3, 4, 5	....	5	600
4	4	....	1	1	....	....	2	2	1	2	....	3 to 6	....	6	800
5	3	....	1	......	....	1	....	1	......	....	....	1 to 4	....	4	700
6	4	....	1	1	....	....	2	2	......	....	....	1 to 9	....	9	600
7	8	1	....	2	1	....	....	2	......	....	a 1 to 6	....	....	6	1,200
8	5	1	....	1	....	2	....	2	......	....	....	1 to 5	....	5	600
9	3	....	1	......	....	1	....	1	......	....	....	1 to 4	....	4	600
10	4	1	....	1	....	....	....	1	......	....	....	1 to 5	....	5	400
11	5	1	....	1, 3	....	b2	....	3	......	....	....	1 to 8	....	8	1,200
12	4½	1	....	......	....	1	....	1	......	....	....	1 to 5	....	5	600
13	4	....	1	......	....	....	1	1	......	1	....	2 to 6	c 7	7	800
14	4	....	1	1	....	....	2	2	1	....	....	2 to 7	....	7	500
15	4	1	....	1	....	2	....	2	......	....	....	1 to 5	....	5	800
16	4	1	....	2	1	....	....	2	......	....	....	1 to 5	....	5	600
17	3	1	....	1	....	2	....	2	......	....	1	2 to 6	....	6	800
18	3	1	....	1	....	2	b 2	2	......	....	....	1 to 4	....	4	400
19	5	1	....	1	....	2	....	2	......	....	....	1 to 5	....	5	400
20	6	1	....	1	....	2	....	2	......	1	....	2 to 6	....	6	1,200
21	4	1	....	......	1	2	....	2	1, 2	....	....	3, 4, 5	....	5	400
22	5	1	....	2	1	3	....	3	......	....	1	2 to 5	....	5	500
23	6	....	1	......	....	....	1	1	......	....	....	1 to 5	....	5	600
24	3	1	....	1	....	2	....	2	......	....	....	1 to 5	....	5	600
25	4	....	1	......	....	....	1	1	1	....	....	2 to 6	....	6	600
Farms using, per cent.	....	60	40	72	16	56	28	....	20	16	16	96	8	......	......
Average	4	....	....	......	....	....	....	2	......	....	....	....	....	5.5	676

a Two-horse, 6-shovel cultivator with shovels used for third cultivation. b Lister. c One-horse sweep.

The farms are worked largely by the owners or by white tenants who supervise their own work. Many Indians live in this region, and a large part of the land is owned by them.

The average-sized farm surveyed is 239 acres, with 163 acres cultivated. Cotton, corn, oats, kafir, and clover are the principal crops grown. A few farmers grow alfalfa on the bottom lands, and much prairie grass is cut for hay. Sweet potatoes, peanuts, watermelons, truck crops, and some fruits are grown for home use. A few cattle and hogs are raised for market, and from the prairie-land farms hay is sold. Cotton, however, is the principal money crop, and the most productive land is planted to this crop.

In preparing a seed-bed for cotton the old cotton or corn stalks are cut up with a stalk cutter during the winter months and the land plowed in early spring. About half the farmers break the land level with a 2-horse or 3-horse plow and lay off the rows with a 1-horse 24-inch sweep which slightly ridges the land. Cotton is usually planted on this low bed. A few farmers plant between the beds, and sometimes a sweep is attached to the planter, which tears down the bed and plants the cotton almost level with the surface.

Another method which about half the farmers employ is to break the land with a 2-horse or 3-horse middle buster, or lister, which leaves it in beds the width apart the cotton rows are to be. These beds are harrowed with a spike-tooth harrow before planting, and the cotton is planted with a 2-horse lister planter, which tears down the bed and leaves the cotton planted almost level with the surface.

After planting, 2-horse cultivators are employed. Just after the cotton comes up many farmers use a spike-tooth harrow. Where the cotton is planted between beds, a 2-horse 1-row lister cultivator, an implement especially designed for use in listed crops, is sometimes employed for the first cultivation; but most farmers use a 2-horse 4-shovel cultivator equipped with small buzzard-wing sweeps instead of shovels. At first 6-inch or 8-inch sweeps are used, but as the cotton plants get larger the sweeps are increased in size to 12 or 14 inches. During the season five or six cultivations are given. After the first cultivation the cotton is chopped to a stand and at the third or fourth cultivation it is again gone over with a hoe, to take out any extra stalks or weeds.

No cover crops are grown and no commercial fertilizer is used. The cultivated lands are fenced and cattle allowed to run at large, so little stable manure is produced.

The principal varieties of cotton grown are Mebane and Rowden.

The most prevalent and troublesome weeds in this county are crab-grass, cocklebur, lamb's-quarters, smartweed, careless weed, Johnson grass, and morning-glory.

SURVEY IN JEFFERSON COUNTY, FLA.

Jefferson County is located in the northern part of Florida. The tillage records for this county (Table XXIV) were taken near Monticello. This is in the Coastal Plain region, and the predominating soil is sand or a sandy loam; the subsoil is clay. The country is level or gently rolling and little drainage is required.

TABLE XXIV.—*Tillage practices with cotton in Jefferson County, Fla., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 8 and 10 to 14 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.					Tillage after planting (all 1-horse implements).						Yield (pounds).
	Depth (inches).	Level.	Into beds.	Rows run with 1-horse 1-shovel plow.	Spike-tooth harrow.	Fertilizer distributor.	Bedded with 1-horse turning plow.	All workings.	Turning plow.	Sweep or scrape.	Cultivator. Disk.	Cultivator. 5-shovel.	Cultivator. Spring tooth.	All cultivations.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	5	1	....	....	......	2	1	2	1	2 to 5	....	....	....	5	500
2	4	....	1	1	......	2	....	2	1	2 to 5	....	....	....	5	700
3	4	1	....	1	......	2	3	3	1	2 to 5	....	....	....	5	600
4	4	....	1	1	......	....	2	2	1	2,3	....	....	....	3	1,200
5	5	1	....	1	......	2	3	3	......	1 to 4	....	....	....	4	500
6	3	....	1	....	......	1	2	2	......	1 to 5	....	....	....	5	500
7	5½	1	....	1	......	2	*a* 3	3	1	2,3,4,6	....	....	5	6	450
8	6	1	....	1	......	2	3	3	1	2 to 5	....	....	....	5	600
9	4	....	1	....	......	1	2	2	1,2	3,4,5	....	....	....	5	750
10	5	1	....	1	......	2	3	3	......	1 to 5	....	3	....	5	700
11	4	....	1	....	......	1	2	2	......	1 to 4	....	....	....	4	750
12	6	....	1	....	......	1	2	2	1	2 to 5	....	....	....	5	450
13	4	1	....	1	......	2	3	3	......	1 to 5	....	2	....	5	750
14	7	1	....	....	1,2	....	....	2	......	....	1,2,3	....	....	3	......
15	4	....	1	....	......	1	2	2	......	1 to 5	....	....	....	5	750
16	8	1	....	1	......	2	3	3	......	1 to 5	....	....	....	5	450
17	4	1	....	1	......	2	3	3	......	1 to 4	....	....	....	4	900
18	4	....	1	....	......	1	2	2	*b* 2	1 to 5	....	....	....	5	600
19	6	1	....	1	......	3	2	3	1	2 to 6	....	....	....	6	800
20	4	....	1	....	......	1	2	2	......	1 to 6	....	....	....	6	750
21	6	1	....	1	......	2	3	3	1	2 to 5	....	....	....	5	700
22	4	....	1	....	......	....	....	......	......	1 to 5	....	....	....	5	500
23	7	1	....	2	1	3	4	4	(*c*)	2 to 5	....	....	....	5	800
24	4	....	1	....	......	1	2	2	......	1 to 5	....	....	....	5	750
25	4	....	1	....	......	1	2	2	......	1 to 5	....	2	....	5	500
Farms using, per cent.	....	52	48	52	8	88	84	......	48	96	4	12	4	....	......
Average	5	....	....	....	......	....	....	2.5	......	....	....	....	....	5	665

a Two-horse cultivator.
b Shovel plow.
c First cultivation with turning plow; fifth cultivation with shovel plow.

Some rural improvements have been made. Most of the leading roads have been improved with sand and clay, but where this has not been done traveling is difficult on account of the deep sand. Fairly good schools are maintained, many farmers have telephones, and the farmhouses are neat and comfortable.

Lumbering and turpentine are important industries in this county. The farms are large, with only about one-third of the land cleared. Many of the stumps have not been removed from the cleared land. The land is owned by white men and worked by negro tenants under the supervision of the owner. Very few white men work their own farms.

No definite rotations are practiced. The principal crops grown are cotton, corn, oats, and watermelons. Hardly enough corn is grown for home use. Watermelons are extensively grown for northern markets. Cowpeas and peanuts are often grown between the corn rows and later pastured with hogs and cattle. Peanuts are often planted alone and pastured with hogs. At the last cultivation of watermelons, cowpeas are sown broadcast over the field. The vines furnish shade for the melons, and with the crab-grass, which comes up voluntarily, they make an excellent hay. Sweet potatoes, sugar cane, cantaloupes, and truck crops are grown for home use. Many pecan groves have been planted, but as yet are not bearing much. Some fruits, especially peaches, are grown for local demands.

Because such a large percentage of the land is not tilled, the cultivated land is fenced and the live stock allowed to run at large. Each farmer has a special brand by which he can identify his stock. Enough cattle and hogs are produced for home use, but few are sold. The farm income is principally derived from the sale of cotton.

The tillage methods employed with cotton are very uniform. If the old cotton or corn stalks are rank, they are cut up with a stalk cutter or chopped off with a hoe, raked up, and burned before the land is plowed. The land is usually plowed in the spring with 1-horse or 2-horse plows. About half the farmers break the land level and about half plow it into beds of the desired width for the cotton rows. Where the land is broken level the cotton rows are laid off with a fertilizer distributor, which also applies the fertilizer. A bed is then made on this fertilizer with a 1-horse shovel or turning plow. Where the land is bedded as broken the fertilizer is either applied in the water furrow between the beds and the land rebedded or the fertilizer is applied on top of the bed and no further preparation is given. The soil is of such a nature that harrowing is seldom necessary. Cotton is planted with a 1-horse planter in rows 4 feet apart, and 1 bushel of seed is planted per acre. After thinning, the stalks are left from 12 to 15 inches apart in the drill. For cultivating after planting, 1-horse implements are employed. About ten days or two weeks after planting, the first cultivation is given with a 1-horse turning plow or a 1-horse sweep. A furrow is plowed on each side of the cotton row and the soil thrown away from the cotton to the middle of the row, leaving the plants on a small narrow ridge. This is known as barring off. After this cultivation, the cotton is chopped to a stand.

A small 1-horse sweep is employed for the next cultivation. Three furrows are required for each row. The entire middle is plowed out, throwing the soil back to the cotton. After this, larger sweeps are used and only two furrows are required for each row. A few farmers use the 1-horse 5-shovel cultivator and the 1-horse spring-tooth cultivator, but most of the cultivating is done with sweeps, starting with 12-inch or 14-inch sweeps and increasing the size at each cultivation up to 20 or 24 inches. In all, four or five cultivations are given. At the third or fourth cultivation the cotton is again gone over with a hoe and any weeds or extra stalks are chopped out.

No cover crops are grown and little stable manure is produced. Commercial fertilizer is used by nearly every farmer. The average application per acre for cotton on the farms studied is 286 pounds.

The varieties of cotton are very much crossed and few farmers have distinct varieties. Those predominating are Toole, Bank Account, and King's Improved.

The most troublesome and prevalent weeds are coffee weed, beggarweed, crab-grass, Bermuda grass, and nut-grass.

SURVEY IN LINCOLN PARISH, LA.

Lincoln Parish is located in the northern part of Louisiana. The tillage records for this county (Table XXV) were taken near Ruston. The soil is sandy or sandy loam, in either case underlain with a clay subsoil. As a rule the land is gently rolling or hilly and is drained by means of surface ditches and small terraces. None of the land is tile drained.

The system of farming is such that elaborate barns and outbuildings are not needed. Less than 50 per cent of the land is cultivated. The farms are of medium size and are usually worked by the owners or by tenants under the supervision of the owners. No definite rotations are practiced, but cotton often follows corn or cotton. The principal crops grown are cotton, corn, and oats. Cowpeas are often planted between the corn rows. The peas are harvested by hand and the vines plowed under. Cowpeas are also sown after oats and the vines cut for hay. Sugar cane, peanuts, sweet potatoes, truck crops, and fruits are grown for home supplies. Cattle and hogs are not grown for market. The farm income is almost entirely from the sale of cotton.

In preparing the land for cotton the old cotton or corn stalks are cut up with a stalk cutter or broken down with a log drag during the winter.

In the early spring the land is plowed with a 2-horse turning plow or with a lister. Beds the width apart the cotton rows are to be are made as the land is plowed. Fertilizer is then put in between these beds and the land rebedded on the fertilizer with a 1-horse or 2-horse turning plow. A few farmers break the land level, lay off the rows with a shovel plow, apply the fertilizer, and with a turning plow make a bed on the fertilizer.

TABLE XXV.—*Tillage practices with cotton in Lincoln Parish, La., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 8 and 10 to 12 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation; 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.					Tillage after planting (all 1-horse implements).				Yield (pounds).
	Depth (inches).	Level.	Into beds.	Rows run with 1-horse 1-shovel plow.	Fertilizer distributor.	Bedded with turning plow.	Spike-tooth harrow.	All workings.	Turning plow.	Side harrow or harrow-tooth cultivator.	Sweep or scrape.	All cultivations.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	6	1	....	1	3	2	4	4	1	......	2, 3, 4	4	750
2	3	....	1	....	....	1	....	1	1	......	2 to 5	5	750
3	3	1	....	1	2	3	4	4	1	......	2, 3, 4	4	750
4	5	....	1	....	....	1	....	1	1	......	2 to 5	5	800
5	3	....	1	....	1	2	3	3	1	......	2 to 5	5	500
6	6	....	1	....	1	2	....	2	1	......	2 to 5	5	300
7	6	....	1	....	1	2	....	2	1	......	2 to 6	6	500
8	4	....	1	....	1	2	....	2	1	......	2 to 6	6	750
9	3	1	....	1	2	3	....	3	....	1	2, 3, 4	4	500
10	4	....	1	1	2	....	....	2	....	1	2, 3, 4	4	500
11	5	1	....	1	2	3	....	3	1	......	2, 3, 4	4	500
12	5	....	1	....	1	2	....	2	1	......	2 to 6	6	750
13	5	1	....	*a*1	2	*a*3	4	4	1	......	2 to 5	5	400
14	5	....	1	....	1	2	3	3	....	*b*1, 2	3 to 6	6	750
15	5	....	1	....	1	2	....	2	1	......	2 to 5	5	600
16	3	....	1	....	1	....	....	1	1	......	2 to 5	5	400
17	5	1	....	1	2	3	....	3	2	*b*1	3 to 6	6	600
18	6	....	1	....	1	2	....	2	1	......	2 to 5	5	700
19	3	....	1	....	....	1	....	1	1	......	2, 3, 4	4	500
20	5	....	1	....	1	2	3	3	....	1	2, 3, 4	4	900
21	5	....	1	....	1	2	....	2	1	......	2 to 7	7	900
22	4	....	1	....	....	1	....	1	....	......	1 to 4	4	750
23	4	....	1	3	1	2	....	3	1	......	2 to 5	5	1,000
24	5	1	....	1	2	3	4	4	1	......	2 to 5	5	500
25	3	....	1	....	1	2	....	2	1	......	2 to 5	5	750
Farms using, per cent	....	28	72	36	84	92	28	......	80	20	100	....	......
Average	4½	....	....	....	....	....	....	2½	....	......	....	5	644

a Lister. *b* Spike-tooth harrow.

Cotton is always planted on a bed with a 1-horse planter. The rows average 4 feet apart, and 1 bushel of seed is planted per acre. After thinning, the stalks are left from 12 to 15 inches apart in the drill.

For cultivating after planting, 1-horse implements are used. The first cultivation is given with a 1-horse turning plow and two furrows are given each row, plowing the earth away from the cotton on each side of the row and leaving the plants on a small ridge. This is known as barring off. After this cultivation the cotton is chopped to a stand. For the following cultivation a 1-horse sweep or scrape is used. At first, 12-inch or 14-inch scrapes are used and three furrows are given each row, plowing the soil back to the cotton. For later cultivations larger sweeps are employed and only two furrows are given each row. At the third or fourth cultivation the cotton is gone over with a hoe again to take out any extra cotton stalks or weeds. In all, five or six cultivations are given.

The principal varieties of cotton grown are Triumph, Simpkins' Prolific, Bank Account, and King's Improved.

The most prevalent and troublesome weeds are crab-grass, Bermuda grass, cocklebur, pigweed, careless weed, and ragweed.

SURVEY IN LAVACA COUNTY, TEX.

Lavaca County is located in the southeastern part of Texas. The tillage records for this county (Table XXVI) were taken near Hallettsville. The soils consist of Houston black clay, some black sand, and large areas of sandy loam, all underlain with a clay subsoil. The land is level or slightly rolling, and little drainage is required.

TABLE XXVI.—*Tillage practices with cotton in Lavaca County, Tex., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 4, 5, and 7 to 9 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.		Tillage after plowing and before planting.			Tillage after planting.				Yield (pounds).
						2-horse cultivator with sweeps.		1-horse sweep.	All cultivations.	
	Depth (inches).	Into beds.	Spike-tooth harrow.	2-horse 1-row lister planter.	All workings.	4-shovel.	2-shovel.			
1	2	3	4	5	6	7	8	9	10	11
1	4½	1	1	2	2	2,3,4	1	......	4	1,000
2	4	1	1	2	2	1 to 5	......	......	5	750
3	3	1	1	2	2	1 to 5	......	......	5	500
4	6	1	......	1	1	1 to 4	......	......	4	500
5	4½	1	1	2	2	1 to 4	......	......	4	600
6	6	1	......	[a] 1	1	1 to 4	......	5	5	500
7	4	1	1	2	2	1 to 5	......	......	5	750
8	6	1	1	......	1	1 to 4	......	......	4	800
9	6	1	1	2	2	1 to 4	......	......	4	700
10	5	1	......	1	1	1 to 4	......	......	4	750
11	4	1	1	2	2	1 to 4	5	......	5	600
12	4	1	1	2	2	1,2,3	......	......	3	750
13	3	1	1	2	2	1,2,3	......	......	3	500
14	7	1	1	2	2	1 to 4	5	6	6	700
15	5	1	1	2	2	2,3,4	1	......	4	400
16	4	1	1	2	2	1 to 4	......	......	4	500
17	......	1	1	2	2	1 to 4	......	......	4	500
18	5	1	1	2	2	1 to 5	......	......	5	750
19	5	1	1	2	2	1 to 5	......	......	5	700
20	8	1	1	2	2	1 to 4	......	......	4	750
21	4	1	1	2	2	1 to 5	......	......	5	550
22	5	1	1	2	2	([b])	......	......	4	750
23	4	1	1	2	2	1 to 4	......	......	4	500
24	5	1	1	2	2	1 to 6	......	......	6	750
25	5	1	1	2	2	1 to 5	......	......	5	500
Farms using, per cent	......	100	88	96	......	100	16	8	......	......
Average	4½	......	......	......	2	......	......	......	4½	642

[a] One-horse sweep. [b] Six-shovel cultivator with sweeps for cultivations 1 to 4.

The region is settled mostly by Germans and Bohemians, and many of the older inhabitants can hardly speak English. They have exceptionally good country homes. This was originally a prairie region, and much of the land is still in the original prairie grass, which is cut for hay.

The average-sized farm surveyed is 210 acres, with only 102 acres cultivated. The remaining land is covered with prairie grasses and scrub oaks. Most of the farming is done by the landowners, and little labor is hired. The farmers usually have large families and both the women and men do every kind of farm work. These people live a very happy life and are fairly prosperous.

The principal crops grown are cotton, corn, prairie-grass hay, and sorghum cane. Most of the cane is sown broadcast and cut for hay. No definite rotations are practiced. Cotton is usually grown on the most productive land. Hardly enough grain is produced to feed the farm stock. Very little fruit is produced and only enough truck is grown for home use and for local markets. Cattle and hogs are grown for home use, but very few are sold.

Practically the only farm product sold is cotton, and only a very small percentage of the food supply is produced on the farm.

The tillage practices employed with cotton are very uniform. Cotton usually follows cotton or corn. Soon after the crops are harvested the old cotton or corn stalks are broken up with a stalk cutter; then in the fall or early spring the land is plowed, and as broken it is thrown into ridges the desired width apart. The breaking is mostly done with 2-horse turning plows, and four furrows are required for each row. A few farmers use a 4-horse middle buster, or lister, and only one furrow is given each row. No further preparation is given until just before planting, when these beds are harrowed with a spike-tooth harrow.

Cotton is planted from March 15 to April 15. For planting, a 2-horse 1-row lister planter is used, which tears down the bed and plants the cotton almost level. The cotton rows average $3\frac{1}{2}$ feet apart and $1\frac{2}{3}$ bushels of seed is planted per acre. After thinning, the stalks are left from 12 to 15 inches apart in the drill.

Cultivation after planting is exceptionally uniform. Every farmer uses a 2-horse 4-shovel riding cultivator equipped with small sweeps instead of shovels. For the first cultivation small 6-inch or 8-inch sweeps are used and are run close to the cotton, but later, after the plants develop more, larger sweeps are used and cultivation is not so close to the cotton. During the season four or five cultivations are given. After the first cultivation the cotton is chopped to a stand and again gone over with a hoe at the third or fourth cultivation to chop out any weeds or extra stalks of cotton. A few farmers use a 1-horse sweep and sometimes a 2-horse 2-shovel cultivator is used, with sweeps attached instead of shovels.

No cover crops are grown and very little stable manure is produced. Organic matter is supplied by weeds and crop residues, which are always plowed under. No commercial fertilizer is used.

The principal varieties of cotton grown are Mebane and Rowden.

The most prevalent and troublesome weeds are morning-glory, crab-grass, buffalo grass, Johnson grass, and cocklebur.

SURVEY IN HOUSTON COUNTY, TEX.

Houston County is located in the eastern part of Texas. The tillage records for this county (Table XXVII) were taken near Crockett, the county seat.

TABLE XXVII.—*Tillage practices with cotton in Houston County, Tex., showing depths of planting, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 8 and 10 to 15 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.					Tillage after planting.							Yield (pounds).
	Depth (inches).	Level.	Into beds.	Fertilizer distributor.	Bedded with turning plow.	Spike-tooth harrow.	Lister planter.	All workings.	1-horse turning plow.	Spring-tooth cultivator.		1-horse sweep or scrape.	2-horse cultivator with sweeps.		All cultivations.	
										1-horse.	2-horse.		4-shovel.	2-shovel.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	3	...	1	...	1	2	...	2	1	...	...	2, 3, 4	...	...	4	750
2	4	...	1	...	1	2	...	2	...	1	...	2, 3, 4	...	...	4	600
3	4	1	...	...	1	2	...	2	1	...	...	2, 3	...	...	3	600
4	3	...	1	...	1	2	...	2	...	1, 2	...	3, 4, 5	...	...	5	500
5	4	...	1	1	2	3	...	3	...	...	1, 2, 3	...	4, 5	...	5	500
6	4	...	1	...	1	2	...	2	...	1	...	2, 3, 4	...	...	4	700
7	4	...	1	1	...	2	...	2	...	1	...	...	...	2, 3, 4	4	400
8	3	...	1	1	...	2	...	2	...	...	1	...	2 to 7	...	7	750
9	5	...	1	1	2	3	...	3	...	...	1	2 to 5	...	...	5	650
10	6	...	1	1	*a* 2	3	4	4	...	1	...	...	2, 3	4	4	750
11	5	...	1	...	...	1	...	1	...	1, 2	...	3, 4	...	...	4	400
12	4	...	1	...	...	1	...	1	1	...	...	2, 3, 4	...	...	4	500
13	5	...	1	1	2	3	4	4	...	...	1, 2	...	...	3, 4, 5	5	600
14	4	...	1	1	2	3	...	3	...	...	1, 2, 3	...	...	4	4	500
15	4	...	1	1	2	3	...	3	...	1, 2	...	3, 4	...	...	4	500
16	6	...	1	...	1	*b* 2	...	2	...	...	1	2, 3, 4	...	...	4	600
17	4	...	1	1	2	*b* 3	...	3	...	...	1	...	2, 3, 4	...	4	500
18	4	...	1	1	2	3	...	3	...	...	1	...	2, 3, 4	...	4	500
19	6	...	1	1	*a* 2	*a* 3	...	3	...	...	1	4	2, 3	...	4	750
20	3	...	1	...	1	2	...	2	...	1	...	2, 3, 4	...	...	4	500
21	5	...	1	1	...	2	...	2	...	...	1, 2	...	3	4	4	750
22	8	1	...	1	*a* 2	3	...	3	1	2 to 5	...	...	...	...	5	800
23	4	...	1	1	2	3	...	3	...	...	1	...	...	2, 3, 4	4	750
24	4	...	1	...	...	1	...	1	...	1	...	...	3	2, 4	4	900
25	3	...	1	1	2	3	...	3	1	...	...	2, 3, 4	...	...	4	500
Farms using, per cent	...	8	92	60	76	100	8	...	20	40	44	52	32	28	...	...
Average	4½	...	...	...	...	...	...	2½	...	...	...	...	...	...	4½	610

a Lister. *b* Log drag. *c* Acme harrow.

The topography of this county is very irregular. Some parts are prairie lands and very level, while other parts are very rolling. The rolling lands are drained by surface ditches. No drainage is required for the level land. The soil is mostly sandy loam with a clay subsoil, but some clay loam is found.

The farms are of good size, averaging 241 acres. Each farm is usually worked by the owner or by a tenant who is supervised by the landowner. Most of the labor is performed by negroes or Mexicans. No definite rotations are practiced. The principal crops grown are cotton and corn. Oats are grown on many farms and cut for hay while the grain is in the dough stage. Cowpeas and peanuts are often planted between the corn rows and pastured by cattle and hogs. Sweet potatoes and truck crops are grown for home use on almost every farm. Some fruit is produced for home supply and for local markets. Cattle and hogs are grown for home use and a few cattle are sold. Only enough corn is raised to feed the farm cattle, and the farm income is derived almost entirely from the sale of cotton.

Cotton is usually planted on land which was in corn or cotton the previous year. In preparing the seed bed for cotton the old cotton or corn stalks are broken up with a stalk cutter or disk harrow during the late fall or winter. Then, in the early spring the land is plowed with a 2-horse turning plow or middle buster and as broken is thrown into beds the desired width apart for the cotton rows. Before planting, the land is rebedded with a turning plow and the beds harrowed with a spike-tooth harrow. Where commercial fertilizer is used, it is applied in the water furrow before rebedding and the land bedded on the fertilizer.

Cotton is planted on the bed with a 1-horse 1-row planter. The rows average 3½ feet apart, and 3 pecks of seed are planted per acre. After thinning, the stalks are left from 12 to 15 inches apart in the drill.

In cultivating, both 1-horse and 2-horse implements are used. The first cultivation is usually given with a spring-tooth cultivator, either 1-horse or 2-horse, and often this implement is used for the second cultivation. For all cultivations after this, sweeps are used. About half the farmers use 1-horse sweeps, putting three furrows to the row, and about half use 2-horse cultivators equipped with sweeps instead of shovels. These 2-horse cultivators are equipped with four small sweeps or with only two large sweeps. During the season four or five cultivations are given.

The cotton is chopped to a stand after the first cultivation and again gone over with the hoe at the third cultivation for a second thinning and to chop out weeds.

No cover crops are grown and little stable manure is produced. About half the farmers use commercial fertilizer. The average application per acre is 202 pounds.

The principal varieties of cotton are Mebane and Rowden. The most troublesome and prevalent weeds are crab-grass, Johnson grass, cocklebur, careless weed, and Bermuda grass.

SURVEY IN MONROE COUNTY, MISS.

Monroe County is located in the northeastern part of Mississippi. The tillage records for this county (Table XXVIII) were taken near Aberdeen, which is the county seat.

TABLE XXVIII.—*Tillage practices with cotton in Monroe County, Miss., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 10 and 12 to 17 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2= second working or cultivation, etc.]

Form No.	Plowing. Depth (inches).	Plowing. Level.	Plowing. Into beds.	Tillage after plowing and before planting. Spike-tooth harrow.	Tillage after plowing and before planting. 1-horse spring-tooth cultivator.	Tillage after plowing and before planting. Bedded with— Turning plow.	Tillage after plowing and before planting. Bedded with— Lister.	Tillage after plowing and before planting. Disk harrow.	Tillage after plowing and before planting. 1-horse 1-shovel plow or fertilizer distributor.	Tillage after plowing and before planting. All workings.	Tillage after planting. Spike-tooth harrow.	Tillage after planting. 1-horse cultivator. Harrow-tooth.	Tillage after planting. 1-horse cultivator. Spring tooth.	Tillage after planting. 1-horse scrape or sweep.	Tillage after planting. 2-horse cultivator with sweeps. 4-shovel.	Tillage after planting. 2-horse cultivator with sweeps. 2-row.	Tillage after planting. All cultivations.	Yield (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	4	1					1			1		1		3 to 6	2		6	500
2	5	1		1			2		3	3	1		2	3 to 6			6	750
3	5	1					1		2	2	1		2, 3	4, 5, 6			6	500
4	4	1		1			2		3	3			1	2 to 5			5	600
5	6									0				2, 5, 6	a1	3, 4	6	500
6	5		1	1						1	1			3, 4, 5	2		5	500
7			1				2		1	2			1, 2, 3, 5	4			5	500
8	5		1	3		2			1	3	1	2	4, 5	3			5	500
9	5		1		3	1			2	3	1		2	3 to 7			7	500
10	5		1	1						1	1			2, 3, 4			4	750
11	8		1	1						1	1			2, 3, 4			4	800
12	4		1	1						1						1 to 4	4	750
13	8		1		1				2	2	1		2	3 to 6			6	750
14	5		1							0				1, 2, 3			3	400
15	6		1			1			2	2		1, 2		3, 4, 5			5	500
16	4		1	1					2	2			1, 2	3, 4, 5			5	500
17	5		1					1		1		1		2, 3, 4			4	500
18	4		1	1					2	2	1			2 to 5			5	500
19	3		1		1				2	2	1		b2	3 to 6			6	750
20	3½		1			1				1			3, 5	1, 2, 4			5	750
21	5		1			2		3	1	3	1	2	6	3, 4, 5			6	750
22	4		1	1						1		1		2. 3, 4			4	500
23	6	1					2	1		2		1		2, 3, 4			4	500
24	3		1	1						1		1		2, 3, 4			4	400
25	5		1	1						1	1			2 to 5			5	700
Farms using, per cent	....	20	80	48	12	20	24	12	48	......	48	32	44	96	12	8	....	....
Average	5	....	....	...	....	...	...	....	....	1.5	...	......	....	....	...	....	5	586

a Six-shovel cultivator with shovels. *b* Turning plow.

This county is very irregular in regard to soil and topography. Most of the upland is sandy loam, with a clay subsoil, but some of the soil is very sandy. The bottom lands, which comprise a large acreage, are mostly clay. A large part of the county is in the prairie region which has a black-clay soil with a clay subsoil. The prairie land is gently rolling, and only surface ditches are required for drainage. In the bottoms a few ditches or canals have been cut. The sandy or sandy-loam lands are rather hilly, with numerous level plateaus and bottoms.

The farms are large, and especially so in the prairie sections. The average size of the farms studied is 299 acres, with 166 acres cultivated. No definite rotations are practiced. The principal crops grown are cotton, corn, oats, cowpeas, and peanuts. Some sweet potatoes, Irish potatoes, and truck crops are grown for home use. Only enough corn and oats are grown to feed the farm live stock. Cowpeas are usually cut for hay or are planted between the corn rows, the peas picked by hand, and the vines pastured by cattle. Peanuts are often grown between the corn rows and pastured by hogs after the corn has been harvested. In the prairie regions alfalfa and Johnson grass are grown extensively. Bermuda-grass pastures are maintained on many farms. Some cattle and hogs are raised for market, and a few dairies are maintained. Enough fruit is produced to supply local markets and for home demands. In the prairie regions hay is an important product, but in all areas the farm income is largely from the sale of cotton.

In preparing a seed bed for cotton most of the work is done in the spring. At some time during the winter or early spring the old cotton or corn stalks are cut up with a stalk cutter, and the land is plowed in the early spring. For plowing, 2-horse teams are generally used, and as broken the land is thrown into beds the desired width apart for cotton rows. On sandy land a few of the small farms use 1-horse plows for breaking, and on some of the larger farms 2-horse middle busters are employed.

Before planting, these beds are harrowed with a spike-tooth harrow. Many farmers rebed the land before harrowing, using the same plow for this as for the first breaking. Fertilizer is applied only on the sandy or sandy-loam lands. The average quantity applied per acre for cotton is 202 pounds. This is applied between the beds, and usually the land is rebedded on the fertilizer. Sometimes this fertilizer is applied on top of the bed just before planting. No cover crops are grown, and very little stable manure is produced.

Cotton is planted during April. A 1-horse planter is used. The rows average 3½ feet apart, and an average of 4 pecks of seed is planted per acre. After thinning, the stalks are left from 12 to 18 inches apart in the drill.

In cultivating after planting, a number of different implements are used. Soon after the cotton is up, the field is harrowed with a spike-tooth harrow or with a 1-horse harrow-tooth cultivator. The next cultivation is given with a 12-inch or 14-inch 1-horse sweep, and three furrows are given each row. Sometimes a 1-horse spring-tooth cultivator is used for the second cultivation. After this, practically all the cultivating is with 1-horse sweeps, the size of the sweeps being increased at each cultivation. A few farms use a 1-horse 1-row cultivator and a 2-horse 2-row cultivator equipped with sweeps instead of shovels. The cotton is usually chopped to a stand after the first or second cultivation and again gone over with a hoe at the fourth cultivation to chop out any weeds or extra cotton stalks. During the season four to six cultivations are given.

Many varieties of cotton are grown. Some of the more popular varieties are Russell's Big Boll, Miller's, King's Improved, Cook's Improved, and Triumph.

The most prevalent and troublesome weeds are crab-grass, Johnson grass, nut-grass, cocklebur, and morning-glory.

SURVEY IN BEXAR COUNTY, TEX.

Bexar County is located in the southern part of Texas, just on the edge of the semiarid regions of the western part of the State. The soil is mostly black clay loam and sandy loam. The subsoil is clay. The tillage records of this county are shown in Table XXIX.

The country generally is rolling or hilly, with broad level bottoms and plateaus. The farming is mostly on the bottom lands. The hills are irregular and rocky, with scant vegetation. Few trees are found in the area except along the streams. The rainfall is very low and is the principal limiting factor in crop production. The soil is of such a nature and the rainfall so scant that no drainage is required. Artesian wells have been drilled near San Antonio, and irrigation is practiced by truck farmers, but it has not been profitable for general farming.

In general, the county is prosperous, and many improvements have been made. Many of the leading roads have been macadamized. Fairly good country schools are maintained. The farmers have exceptionally good farmhouses and outbuildings. Telephones are found in many farm homes. Most of the farmers work their farms and hire what extra labor is needed. The people are largely of German and Bohemian descent, but the hired laborers are mostly Mexicans.

The farms are rather large. The average size of the farms surveyed is 295 acres, but much of this is rough waste land. An average of only 130 acres is cultivated.

No rotations are practiced. The principal crops grown are cotton, corn, sorghum cane, oats, and milo. Feterita is becoming an important crop. Cotton is the principal money crop. Hardly enough grain is grown to feed the farm animals. Feterita and milo are grown for grain. One of the most important crops is sorghum cane sown broadcast and cut for hay. Often two crops are cut a year, with a total yield of 3 or 4 tons. Much of this hay is baled and sold. Only enough fruit and vegetables are grown to supply home demands. Very few cattle and hogs are raised for market.

The principal sources of farm income are corn, hay, and cotton.

In preparing the land for cotton very uniform methods are employed. If cotton follows cotton or corn the old stalks are cut up with a stalk cutter soon after the crop is harvested. Most of the land is plowed in the fall. For breaking, 3-horse and 4-horse sulky and gang plows are generally employed. The land is plowed level and no other preparation is given until the following spring, just before planting time, when the land is harrowed with a spike-tooth harrow. Many farmers use a 2-horse 4-shovel cultivator for laying off the rows, which leaves the land slightly ridged. These ridges are the distance apart of the cotton rows. If the land is rough or cloddy, sometimes a disk harrow is used, but this is not a common practice.

TABLE XXIX.—*Tillage practices with cotton in Bexar County, Tex., showing depths of plowing, implements used in order of use, number of times each is used, and normal acre yields.*

[In columns 5 to 8 and 10 to 15 the figures show the order in which the implement was used on the several farms; as, 1=first working or cultivation, 2=second working or cultivation, etc.]

Farm No.	Plowing.			Tillage after plowing and before planting.					Tillage after planting (all with cultivators).							Yield (pounds).
				Harrow.		2-horse.			2-horse 6-shovel with—		2-horse 4-shovel with—			1-horse harrow tooth.	All cultivations.	
	Depth (inches).	Level.	Into beds.	Spike-tooth.	Disk.	4-shovel cultivator.	1-row lister planter.	All workings.	Shovels.	Sweeps.	Shovels.	Sweeps.	Sweeps and shovels.			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	5	1	...	1	...	...	2	2	1	2,3,4	...	...	...	...	4	450
2	6	1	...	1	...	...	2	2	...	1 to 6	...	...	...	...	6	400
3	4	1	...	1	...	...	2	2	1,2,3	...	...	...	...	4,5	5	500
4	8	1	...	1,2	...	...	3	3	1	...	3,4	...	2	...	4	400
5	6	1	...	1	...	...	2	2	1	...	...	2 to 5	...	...	5	400
6	8	1	...	1	...	...	2	2	1 to 5	...	...	...	...	...	5	500
7	8	1	...	1	...	...	2	2	1 to 5	...	...	...	...	...	5	400
8	4	1	...	1	...	2	3	3	...	...	1,3,4	2,5,6	...	...	6	400
9	6	1	...	...	...	1	2	2	...	...	1 to 4	...	...	...	4	500
10	6	1	...	1	...	...	2	2	...	...	1,2,3	...	...	...	3	400
11	6	1	...	1	...	2	3	3	...	...	1 to 5	...	...	...	5	500
12	3	1	...	...	1	2	3	3	...	...	1 to 7	...	...	...	7	500
13	6	1	...	2,3	1	...	...	3	2,3	...	...	...	...	1,4 to 7	7	500
14	6	1	...	1	...	2	3	3	...	...	1,2	3,4	...	...	4	500
15	6	1	...	1	...	2	3	3	...	...	1,4,5,6	2,3	...	...	6	600
16	6½	1	...	1	...	...	2	2	...	1	...	...	2,3	...	3	400
17	6	1	...	1	...	...	2	2	1	2,3,4	...	...	...	...	4	750
18	6	...	1	1	...	...	2	2	4	2,3	1	...	...	...	4	500
19	5	1	...	1,2	...	...	3	3	...	...	...	3,4,5	...	1,2	5	500
20	5	...	1	1	...	...	2	2	...	...	1,3,4	2	...	...	4	400
21	5	1	...	1	...	...	2	2	...	...	...	...	1 to 4	...	4	400
22	7	1	...	1	...	...	2	2	1 to 4	...	...	...	...	...	4	400
23	8	1	...	1	...	2	3	3	1,2,3	...	...	...	...	...	3	500
24	6	1	...	...	...	1	2	2	...	...	2,3	...	1	...	3	500
25	5	1	...	...	...	1	2	2	1,3,4,5	2	...	...	...	...	5	500
Farms using, per cent	...	92	8	84	8	36	96	...	48	24	44	24	16	12	...	...
Average	6	...	...	...	...	...	...	2.5	...	...	...	...	...	...	5	472

Usually cotton is planted in March or the first part of April. A 2-horse 1-row lister planter is used, which leaves the rows level or slightly listed.

The rows average $3\frac{1}{2}$ feet apart, and an average of 3 pecks of seed is planted per acre. After thinning, the stalks are left from 15 to 20 inches apart in the drill.

In cultivating after planting, 2-horse 4-shovel or 6-shovel cultivators are employed almost entirely. These cultivators are sometimes equipped with shovels or with sweeps, and sometimes with shovels near the cotton and sweeps for the middle of the row.

Many farmers use small sweeps instead of shovels for the later cultivations. During the season four or five cultivations are given. After the first cultivation the cotton is chopped to a stand and again gone over with a hoe at the third or fourth cultivation to chop out weeds or extra stalks of cotton.

No cover crops are grown, and very little stable manure is produced. No commercial fertilizer is used.

The principal varieties of cotton grown are Mebane, Triumph, and King's Improved.

The most prevalent and troublesome weeds are careless weed, Johnson grass, morning-glory, and buffalo grass.

SUMMARY.

The results of these studies are presented to portray the prevailing conditions, customs, and tillage practices found in the various regions where cotton is grown. No attempt is made to make recommendations based on the data presented.

These studies clearly show that yields of cotton are governed largely by climatic conditions, the inherent fertility of the soil, the quantity of commercial fertilizers used, and the character of tillage given. The yields of cotton are directly related to the amount of tillage given after planting.

The principal types of drainage employed in the cotton belt are terraces and surface ditches, open ditches, and tile drains. The type of drainage employed is determined by the character of the soil, the topography, the amount of rainfall, and the value of land.

Tillage before plowing is primarily for the purpose of cutting up the stalks and weeds of the previous season's growth, so that they will not interfere with cultivation. Little thought is given to benefits derived from pulverizing the surface soil before breaking.

Whether land be plowed in the fall or spring is governed largely by the previous crop and by the type of soil. The conditions in the cotton belt are such that most of the land is plowed in the spring.

The depth of plowing land for cotton is largely determined by the type of soil. The light sandy or loamy soils are plowed slightly deeper than the heavy clay soils. There is little or no relation between the depth of plowing and the yield of cotton. In preparing the land after plowing for cotton, the type of soil and the prevailing tillage methods determine what implements are used and the amount of tillage given.

In planting cotton, 1-horse planters are chiefly used. The time of planting is governed largely by the type of soil and the climatic conditions. Cotton is generally planted on a slight bed, and in only a few areas where dry weather prevails during the growing season is it ever planted level or listed.

Cotton is sown in drills from 3 to 4 feet apart and thinned to a stand at the second and third cultivations. After thinning, the stalks are left from 12 to 18 inches apart in the drill.

The amount of cultivation given after planting is directly related to the yields of cotton obtained. This was not found to be true in the cultivation of corn.[1]

In the cotton belt where crops which add organic matter to the soil, such as hay and pasture, enter little into the rotations practiced, the percentage of cultivated land grown in cotton each year does not appear to affect the yields of cotton obtained. In those areas where heavy applications of commercial fertilizer are made every year and where from 40 to 50 per cent of the cultivated land is planted to cotton, there appears to be a slight increase in the yields of this crop.

The cotton belt may be grouped into four divisions: (1) The Delta areas, (2) the South Atlantic division, (3) the Intermediate areas, and (4) the Southwestern division. For each division the general customs, practices, and conditions are fairly uniform.

The methods employed in each division are, generally speaking, those most advisable under the existing conditions.

It is believed from these studies that the kind of tillage given cotton and the tillage implements used are governed largely by economic conditions, topography, type of soil, and, not least, custom. The amount of tillage given is determined largely by the kind and number of weeds, the economic conditions, and the prevailing weather.

[1] See U. S. Dept. Agr. Bul. 320, previously mentioned.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 512

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C. PROFESSIONAL PAPER April 5, 1917

PREVENTION OF THE EROSION OF FARM LANDS BY TERRACING

By

C. E. RAMSER, Drainage Engineer

CONTENTS

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PREVENTION OF THE EROSION OF FARM LANDS BY TERRACING.

By C. E. Ramser, *Drainage Engineer.*

CONTENTS.

INTRODUCTION.

The existence of vast areas of so-called worn-out hill lands throughout the United States may be attributed chiefly to soil erosion, due to the natural agencies of wind, frost, and rain. In most localities wind and frost, owing to their comparatively slow processes, play but a minor part in the depletion of the soil and the ultimate destruction of good farm lands. It is the failure of the soil to absorb the rain water which falls upon it that presents by far the most serious aspect of the problem. It is estimated[1] that the Potomac River each year carries off in solution about 400 pounds of solid

[1] Bulletin 17, North Carolina Geological and Economic Survey, p. 21.

Note.—This bulletin treats of terracing as a means of preventing erosion of hillside land. It describes the different types of terraces and points out the applicability of each to the various kinds of soil and topography. It discusses the principles of terrace design. While the investigations upon which the recommendations are based were made in the Southern States, the information is applicable generally to any State in the humid section.

matter per acre of land drained, containing plant food sufficient to produce a crop. Unless this loss be replaced by natural agencies or by the application of fertilizer, it is obvious that the land soon will deteriorate greatly in productiveness and eventually be abandoned.

In addition to the loss of the soluble elements of the soil, a noticeable impairment occurs in the physical condition of the soil. When the moving water washes the soil particles from the surface of the hillside and deposits them on the land below, the heavier particles, or the sandy constituents of the soil, are deposited first, and the finer, or clay, parts last. Since neither pure sand nor pure clay possesses the productive characteristics observed in a soil composed of the proper intermixture of sand and clay particles, it is apparent that the effect of this sorting process is to diminish greatly the fertility or productive power of the soil. Hence, not only the eroded land suffers but also the land at a lower level upon which the eroded material is deposited. Portions of the flood plains of small streams often are covered with a layer of sand, the fertility of the land so covered being practically destroyed, since it is a most difficult task again to build up a productive soil over such areas. Drainage channels, also, constructed at considerable cost, often become filled with soil washed from the hill lands. (See Pl. I, fig. 1.) As a result the adjoining bottom land reverts to swamp and becomes unprofitable for cultivation.

FORMS OF EROSION.[1]

Erosion due to moving water occurs in two forms—sheet washing and gullying. Small areas are practically ruined by gullying (Pl. I, fig. 2), while sheet washing (Pl. II, fig. 1) diminishes the productive power of large areas.

Gullying generally is the most dreaded of the two types on account of its more apparent destructive effects. Where the ravages of erosion proceed unchecked, deep gullies invariably develop in the field. Their appearance causes not only absolute loss of land and inconvenience in cultivating, but a marked lowering in the water table, with a possible accompanying inability of the soil to retain the proper moisture content for the production of crops and to withstand periods of drought.

The injury due to sheet washing, which occurs throughout the United States, generally is underestimated and is regarded by many farmers as of no particular consequence. It is this type of erosion that slowly carries away the very fertility of the soil without apprising the farmer—except through slightly diminished crop yields each year—that the application of remedial measures is imperative in order to save his farm. To the very slowness of its action can be

[1] For a more extended discussion of the translocation of soils, see U. S. Dept. Agr. Bul. 180, by R. O. E. Davis.

ascribed the difficulty often encountered in convincing the landowner that destructive erosion is taking place on his farm.

In some sections of the United States, particularly in the South, erosion is assisted materially by the alternate freezing and thawing of saturated soil. (Pl. II, fig. 2.) The freezing process upheaves a thin layer of the soil near the surface. As this layer of loosened soil thaws, it settles, with a tendency to move slightly down the slope. It is very common for heavy rains to occur directly after the thawing period and wash away the loosened soil from the surface of the field. Probably no other combination of natural conditions could operate more effectually to rob a field of its most fertile soil in the same period of time.

METHODS OF PREVENTING EROSION.

Erosion is due chiefly to the free movement of water over the surface of the land, which carries off particles of soil. If all rain water were absorbed by the ground upon which it falls, soil erosion would be reduced to a minimum. It is obvious, therefore, that in order to prevent or reduce erosive action the soil must receive treatment that is conducive to the admission and the storage of large quantities of rain water; and methods must be employed to reduce the velocity, and thereby the transporting power, of the run-off water.

Since the storage capacity of a soil depends upon its porosity, any treatment which results in an increased porosity of the soil will reduce erosion materially. This porous condition usually is obtained directly by deep plowing and by a thorough incorporation of organic matter in the soil. Methods of subsurface drainage which lower the ground water level improve the porous structure of the soil and increase its ability to absorb surface water. The treatment of cover, such as seeding land to pasture, growing timber, and planting cover crops in the winter, tends to check and diminish erosion greatly. Other methods which retard the flow of the water and conduct the excessive run-off from the field with a reduced amount of erosion, are contour plowing, hillside ditching, and terracing.

It is the purpose of this paper to deal primarily with the prevention of erosion by means of terracing; but since all of the methods of prevention enumerated above tend to mitigate the destructive effects of erosion, some of them should be used invariably in connection with terrace systems. The manner in which each contributes to the prevention of erosive action will be described briefly.

DEEP TILLAGE AND APPLICATION OF HUMUS.

By deep plowing the absorptive power and reservoir capacity of a soil is increased greatly. It is said [1] that 10 inches of loose, plowed

[1] Soil Report N. 3, Illinois Agricultural Experiment Station, p. 16.

soil will absorb 2 inches of rainfall. The incorporation of organic matter or humus in a soil adds materially to its moisture-holding capacity. This is best accomplished by plowing under deeply, manure, stubble, stalks, and various cover crops. This organic matter, in a decomposed state, is capable of absorbing considerable water and forms a richer and deeper top soil.

USE OF COVER CROPS.

Vegetation or cover crops will protect the soil in four ways: (1) by holding rain water on the surface for a time, thus giving the soil a better opportunity to absorb the water; (2) by keeping the soil open through the growth of the roots, which form passages for the water to reach the subsoil; (3) by holding the soil particles together through the binding power of the roots; and (4) by reducing the movement of soil particles through diminishing the velocity of surface water. Cover crops usually are grown during the winter or when the land is not being used for other crops. Their importance as a means of protecting land from erosion at such times can not be emphasized too strongly. Vetch, clover, cowpeas, wheat, and rye are used commonly for this purpose. It can be said generally that good farming and the use of cover crops go hand in hand.

PRACTICE OF LEVEL CULTURE.

Contour plowing and the following in general of practically level lines in farm operations tend to check the surface flow down a slope and to retain the water where it falls. In cultivating crops each row is banked up and a shallow depression which holds the surface water is left between the rows. Thus the absorption by the soil of this impounded water is facilitated and the rapid run-off down the slope, with its destructive eroding power, often is entirely eliminated in case of ordinary rains. Contouring contributes also in a considerable degree to the conservation of moisture on hill lands. The very apparent benefits of this practice merit its universal use on lands subject to erosion.

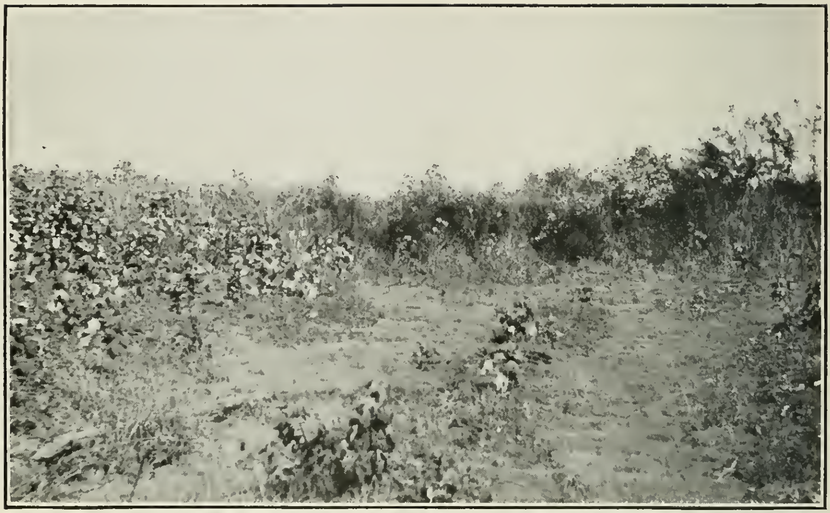
PASTURING AND FORESTING.

Often it seems impossible to prevent erosion on lands with excessive slopes. No attempt should be made to cultivate such areas but they should be seeded to meadow or pasture and usually retained as such. In well-sodded land the soil is not exposed directly to the erosive action of the water, so that erosion is much less destructive than in cultivated fields.

In many sections of the country timberland on excessively steep slopes has been cleared for cultivation, and in many instances after

FIG. 1.—DITCH PARTIALLY FILLED WITH SANDY SOIL ERODED FROM UPLAND.

FIG. 2.—EROSION IN THE FORM OF GULLYING.



D178

FIG. 1.—EROSION IN THE FORM OF SHEET WASHING.

4286A

FIG. 2.—EROSION ASSISTED BY ALTERNATE FREEZING AND THAWING OF THE SOIL.

clearing it was found impossible to control or check the erosion. Such lands should be reverted to timber; otherwise the ravages of erosion will reduce it soon to a state of barrenness. It is known that erosion is least active in forested areas, because of the penetration and binding power of the roots and the accumulation of a thick layer of leaves and organic matter on the soil surface. The soil possesses great coherence and power of resistance to the erosive action of the water and the layer of humus protects the surface and also absorbs considerable water.

UNDERDRAINING.

It can be seen readily that by the underdrainage of land to carry off the excess water from the soil space is created for the reception of more water from the surface. The water falling upon the surface sinks into the soil, percolates through it, and is conducted away by the underdrains to an open drainage channel without running over the surface and causing destructive erosion. Entrapped air, which often prevents the entrance and free movement of water in the soil, finds a means of escape through subdrainage channels. The physical condition of the soil is altered by underdrainage through the aeration and flocculation of the soil particles. A perceptible expansion and a slight upheaval of the soil take place, resulting in an increase in the size of the individual pore spaces. Hence, the rainfall percolates more easily and quickly into the soil and a diminution in the run-off follows. This system of draining is accomplished best by the use of tile drains.

USE OF HILLSIDE DITCHES.

Hillside ditches, as the name implies, are ditches constructed on hillsides to intercept run-off water and carry it at a low velocity to the nearest open drainage channel. Wherever this method of preventing erosion is employed there is likely to be a constant, perceptible draining off of the finer particles of soil, and a continual enlargement of the ditch takes place, the extent depending upon the amount of fall given to the ditch. (See Pl. III, fig. 1.) It is inadvisable, therefore, to resort to this method except when it is necessary to intercept surface water from adjoining higher land on which methods of preventing erosion are not employed. Sometimes hillside ditches are constructed to serve as outlets for systems of graded terraces where natural drainage outlets are not available.

TERRACING.

The greatest benefits from the foregoing methods of prevention come when they are applied in connection with a system of terraces.

Terracing affords the best means of conserving the hillside soils against the washing due to heavy rains.

A field trip was made by the writer through the States of North Carolina, South Carolina, Georgia, Alabama, and Mississippi for the purpose of studying the nature, causes, and effects of erosion, and more particularly the method of preventing erosion by means of terraces. Surveys of terraced fields which afford typical examples of every form of terrace in use were made with a view to deducing from a close study of the field data comprehensive and definite instructions for the design and construction of adequate and efficient systems of terraces. It was found that a great diversity of opinion exists among the landowners as to the best form of terrace and in the rules employed in planning a system of terraces. However, this difference of opinion, in most cases, could be attributed directly to varying conditions of soil and topography or to differences in farming methods.

The subject of the proper methods of terracing was discussed at length with experienced farmers—men who are pioneers in the practice of terracing and who are interested vitally in the preservation of their lands for themselves and their posterity. The deductions and conclusions reached are the result of an endeavor to treat from an engineering standpoint the information obtained from actual observation of field conditions in connection with the data derived from field surveys and the advice and opinions of the best informed and most experienced farmers.

DEFINITION AND CLASSIFICATION OF TERRACES.

As applied to the protection of farm lands, a terrace is any arrangement or disposition of the soil the object of which is to retard the rapid movement of surface water and thereby arrest the process of erosion. According to the earliest practice, terracing consists of building land up in a series of level areas resembling stair steps, the interval between the risers being horizontal and the riser itself being vertical or nearly so. This type of terrace has long been used extensively in Europe and China and is used to a great extent on the steeper lands in the United States. It is known generally as the level bench terrace, but to avoid confusion in the use of the term "level" it will be referred to in this paper as the horizontal bench terrace. Strictly speaking, this is the only true terrace, but the word "terrace" in this country is applied also to ridges of soil thrown up and located in such manner as to prevent the rapid flow of water down a slope. This type of terrace will be referred to in this paper as the ridge terrace to distinguish it from terraces of the bench type. The following classification (fig. 1) of terraces shows the various forms of bench and ridge types.

The bench type of terrace is subdivided into two classes, the horizontal and the sloping, the essential difference between the two being shown clearly by figure 1. Practically all terraces of the bench type are level, which means that they have no fall along the direction of their length to drain off surface water to the edges of the field or to an outlet channel.

The ridge type of terrace is subdivided into two general classes, the graded and the level, depending upon whether it has fall in the direction of the terrace to carry off the surface water. Graded and level-ridge terraces are subdivided further into two classes with respect to breadth of base, namely, the broad-base and the narrow-base forms. The broad-base graded terrace is subdivided again with

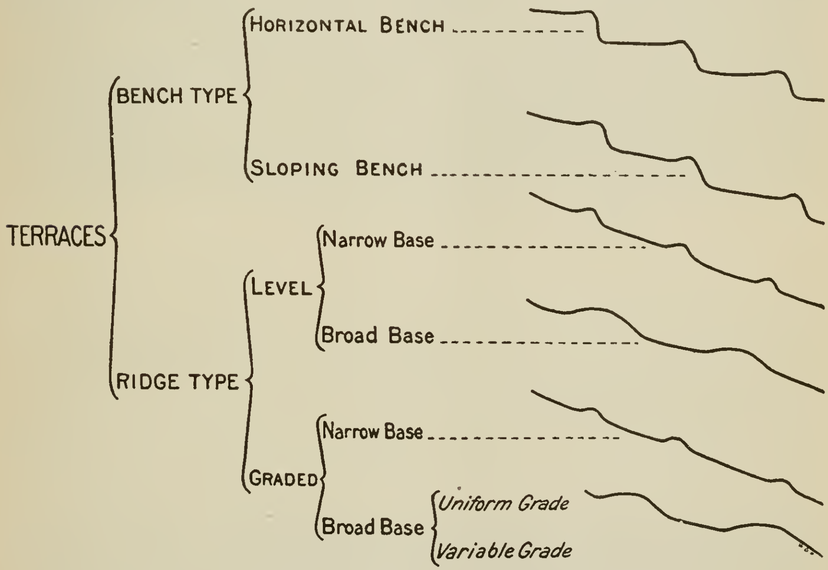


FIG. 1.—Classification of terraces.

respect to grade, the uniform-graded and the variable-graded terraces. Figure 2 shows actual profiles taken on terraced fields and illustrates the various types.

THE BENCH TERRACE.

Bench terraces, as stated, are of two classes—the horizontal and the sloping—depending upon whether the bench is horizontal or sloping. There are not many good examples of the true horizontal-bench terrace in this country, while the sloping-bench terrace is quite common. (See fig. 2–A, and Pl. III, fig. 2.) This is due to the fact that the horizontal bench is developed from the sloping bench by the gradual movement of the soil down the slope, owing to erosion, and to the use of the hillside plow, which always throws the soil down the slope. The time required for the leveling down of a sloping bench depends upon the amount of soil moved down the slope each year and upon the vertical distance between the terraces. It is necessary to maintain a shoulder of earth at the lower side of the bench for sloping-bench terraces, and it is advisable that this be done for horizontal-bench terraces, for the purpose of retaining that portion of the rain water which does not sink into the soil. This shoulder and the lower side of the embankment should be seeded to grass. (See Pl. IV, fig. 1.) The sod permits the use of a steep slope on the lower

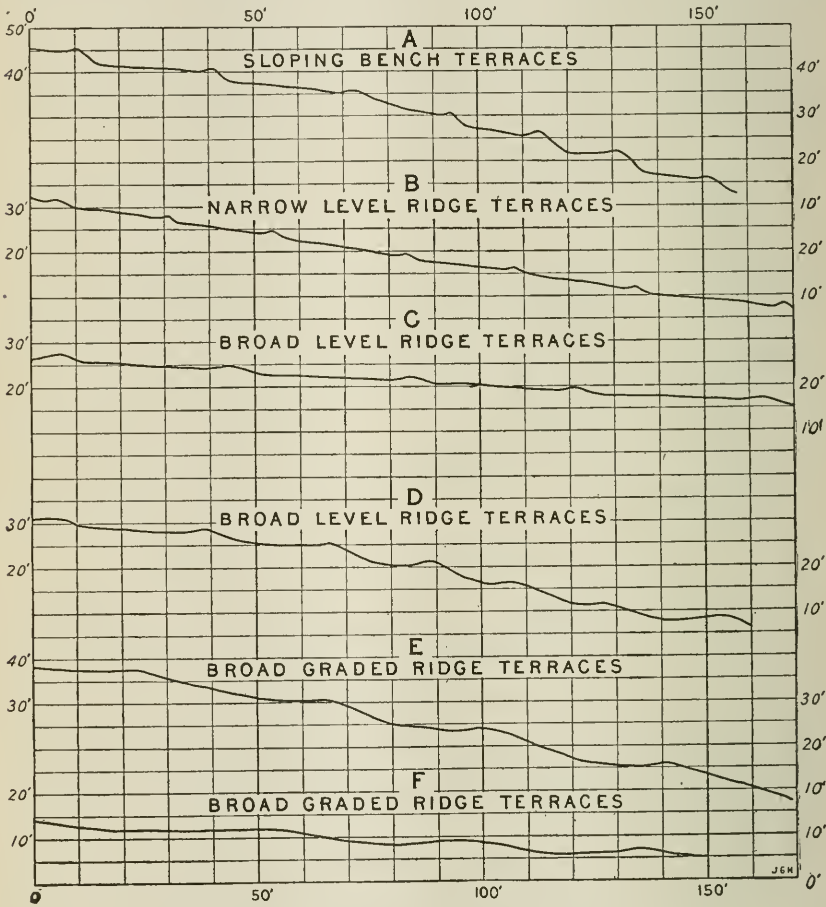


FIG. 2.—Actual profiles of terraced fields, taken across terraces.

side of the embankment and protects both the shoulder and the embankment from erosion due to surface water overtopping the shoulder. The leveling-down process mentioned above sometimes is continued until the slope of the bench is reversed. Thus, the water falling on the bench will flow to the foot of the embankment above. In this case no shoulder will be required to prevent the water from washing over and eroding the embankment.

D177

FIG. 1.—HILLSIDE DITCH WHICH IS WASHING BADLY.

D663

FIG. 2.—FIELD OF SLOPING BENCH TERRACES.

D176

FIG. 1.—VIEW OF LOWER SIDE OF SLOPING-BENCH TERRACE EMBANKMENT.

D168

FIG. 2.—FIELD OF NARROW-BASE LEVEL-RIDGE TERRACES.

Figure 3 shows a cross section of two adjacent sloping-bench terraces, with the various dimensions designated by letters for reference.

Surveys were made of a number of fields in the Piedmont sections of Georgia and South Carolina which have sloping-bench terraces. The average dimensions of the terraces in each field were determined. The minimum and maximum of these averages are shown in the following table:

Actual dimensions[1] of sloping-bench terraces.

Dimension.	Field averages.	
	Minimum.	Maximum.
Height of shoulder, *h* .... feet..	0.4	0.8
Width of upper side of shoulder, *b* .... do....	1.8	2.3
Vertical distance between terraces, *v* .... do....	3.4	10.4
Ratio of c to *d* .... per cent..	58	121
Slope of land .... do....	5.5	28

[1] See fig. 3.

A comparative study was made of the conditions existing in the fields and the data obtained from the surveys with a view to ascer-

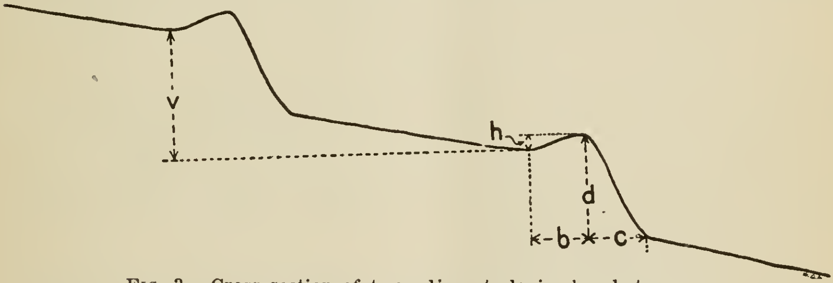


FIG. 3.—Cross section of two adjacent sloping-bench terraces.

taining proper values to use in constructing a terrace of this style. The best terraces were found where the greatest height and width of shoulder were used with the smallest vertical distance between the terraces. It is believed that the height of shoulder (*h*) should be not less than 0.5 foot for horizontal-bench terraces or less than 1 foot for newly constructed sloping-bench terraces, and that the width (*b*) should be not less than 2 feet for the former or less than 3 feet for the latter. The vertical spacing between the terraces should be governed by the type of soil, the slope of the land, and the ease of starting and maintaining a heavy sod on a steep and high embankment. The best practice indicates that this spacing never should be less than 3 feet or more than 6 feet. The smaller spacing should be used on gently sloping land while the greater spacing applies to steep land. The question of proper spacing depends to a great extent upon the care and maintenance of the terraces. Unless considerable attention is to be given to the maintenance of the terrace banks the smaller spacing should be used. For the 3-foot spacing a greater number of terraces are required and narrower benches result, but the terraces are easier to build and maintain than for a greater spacing. However, many farmers favor the wider benches because of the fewer terraces required and the fact that it is more convenient to cultivate the field in a few broad strips than in a greater number of narrow ones. In other words, they are willing to incur a greater loss by erosion for the sake of greater convenience in cultivation.

The slope of the terrace bank, or the ratio of c to d, was found to range from 58 to 121 per cent. It is believed that this bank could be maintained easily at a slope of $\frac{1}{2}$ to 1, or 50 per cent. This would reduce the area of waste land in a terraced field.

The curves in figure 4 show the widths of bench for different vertical spacings on land of various slopes. Each curve is drawn for a certain vertical spacing between terraces. The widths of bench are computed for horizontal-bench terraces having a slope of $\frac{1}{2}$ to 1 for the terrace banks. When constructed and maintained properly, bench terraces give excellent protection against erosion. However, many landowners object to this terrace on account of the difficulty of moving farm machinery from one bench to another, the necessity of cultivating each bench separately, the loss of the land occupied by the uncultivated embankments, and the growth of weeds and grass on the embankment, which robs the adjacent cultivated soil of its plant food and tends to seed the entire field to weeds and objectionable grasses. These reasons are sufficient to militate against the use of this terrace except on steep slopes where no form of cultivable terrace can be employed.

The best practice indicates that the bench terrace should not be used on slopes exceeding 20 per cent. However, they are actually in use on slopes up to 30 per cent, with a vertical interval of 8 to 10 feet; but in such instances the labor of cultivating the narrow benches and of maintaining the high embankments is considerable, and it is believed that such slopes could be devoted more profitably to pasture or timber.

THE LEVEL-RIDGE TERRACE.

The narrow-base form.—The narrow-base level-ridge terrace (see fig. 2–B, and Pl. IV, fig. 2) is used to a great extent throughout the Piedmont region of the South. It is essentially the first stage in the construction of a bench terrace, but methods of plowing are employed to prevent it from developing into a terrace of the bench type. It is built usually 3 to 5 feet wide at the base and from one-half to 1 foot high. Where these terraces are sodded heavily they render satisfactory service on pervious soils and slopes not greater than 5 to 8 per cent. They should be spaced from 2 to 3 feet apart in vertical distance. A close spacing reduces the volume of water which collects above the terraces, and the sodded surface prevents erosion of the terrace due to impounded water overtopping it.

This type of terrace is cheap to construct, easy to maintain, and affords a very convenient guide row in plowing and planting. The

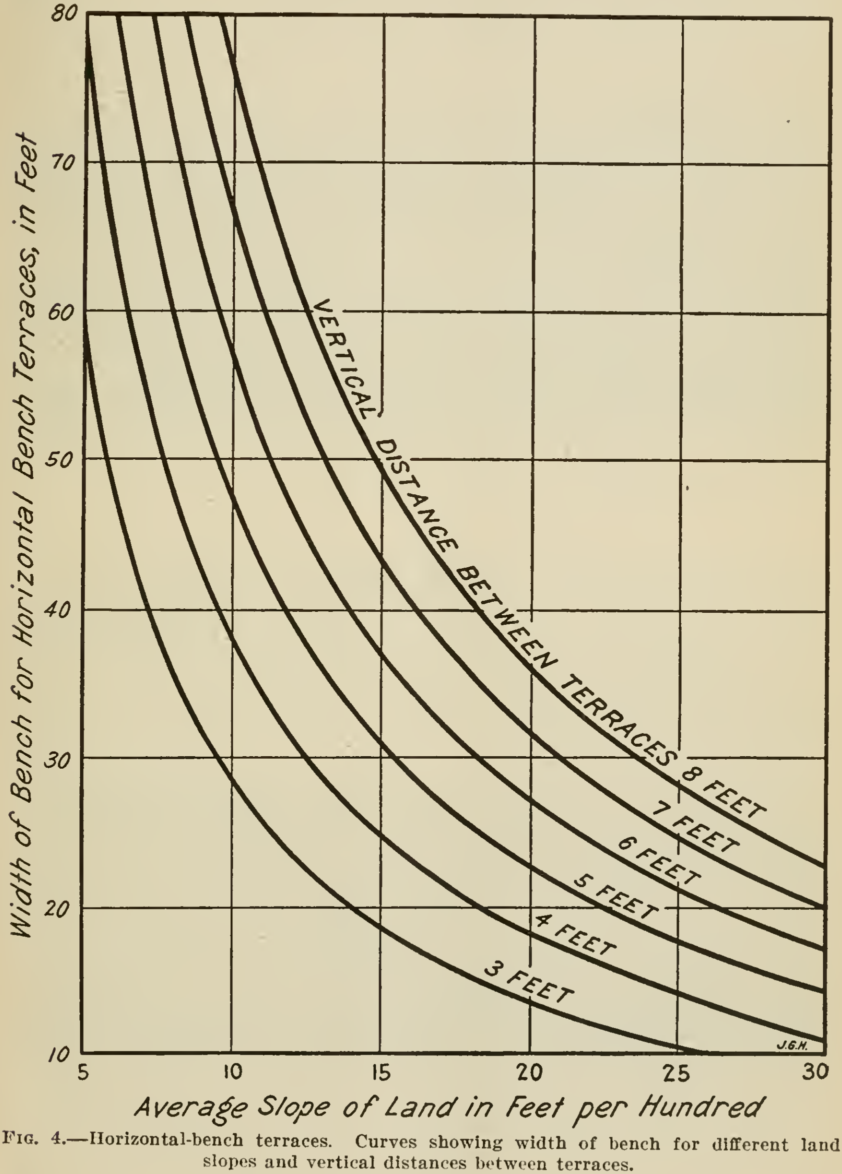


FIG. 4.—Horizontal-bench terraces. Curves showing width of bench for different land slopes and vertical distances between terraces.

principal objections to its use are (1) the land occupied by the sodded terrace reduces the total amount of tillable land in the field; (2) the growth on the terrace saps the strength from the adjoining soil, resulting in a dwarfed plant growth on either side of the terrace;

and (3) the weeds which often are allowed to grow on the terrace tend to seed the entire field, and harbor objectionable insects in the winter. Owing to these objections, this type of terrace is losing favor rapidly among the most advanced farmers.

Some attempts have been made to cultivate this terrace and thus do away with the objectionable features, but such attempts have been attended with very little success, except where the soil is very sandy and capable of absorbing most of the rain water as fast as it falls. Where this water is not absorbed readily by the soil, it concentrates above the terrace, generally breaks it and rushes down the slope, usually washing a deep gully and carrying away large quantities of fertile soil.

The broad-base form.—The many disastrous attempts to cultivate the narrow-base level-ridge terrace on all types of soil have led to the development of a terrace with a broader base, known as the broad-base level-ridge terrace. (Fig. 2–C and D, and Pl. V, fig. 1.) The broad-base embankment of earth provides the strength necessary to withstand the weight of the impounded water above, and the ter-

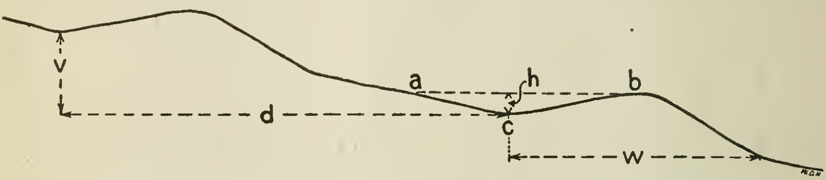


FIG. 5.—Cross section of two adjacent broad-base level-ridge terraces.

race is built sufficiently high to hold all run-off water from the drainage area above the terrace.

Surveys and examinations were made of several fields provided with these broad-base terraces in Alabama, Georgia, North Carolina, and South Carolina, and much information was obtained from farmers with many years of experience in the successful use of this type of terrace. A thorough study has been made of the data collected in connection with existing field conditions for the purpose of standardizing the dimensions employed in the construction of this terrace for different slopes of land and types of soil.

Figure 5 represents a cross section of two adjoining broad-base level-ridge terraces, with the various dimensions designated by letter. The vertical height of the terrace above the point c is represented by h; w is the width of the base of the terrace, d the horizontal distance, and v the vertical distance between terraces. These dimensions were obtained from surveys of eight fields representing the best practice in the use of this form of terrace. The average dimensions of the terraces in each field were determined. The minimum and maximum of these field averages are shown in the following table, together

D660

FIG. 1.—VIEW OF LOWER SIDE OF A BROAD-BASE LEVEL-RIDGE TERRACE; COTTON ROW ON TOP OF TERRACE.

D193

FIG. 2.—TERRACE OUTLET IN DEPRESSION OF FIELD, SEEDED TO GRASS TO PREVENT EROSION.

with the absolute minimum and maximum values found in the surveys:

Actual dimensions[1] *of broad-base level-ridge terraces.*

Dimension.	Absolute minimum.	Absolute maximum.	Field averages.	
			Minimum.	Maximum.
Base width of terrace, w .... feet..	5	18	6.8	11.6
Height of terrace, h .... do....	.5	1.6	.8	1.4
Vertical distance between terraces, v .... do....	1.9	6.1	2.7	4.8
Slope of land suraface .... per cent..	1.4	21.5	2.7	11.8

[1] See fig. 5.

From a study of the above data and observation of field conditions, it is believed that a broad-base level-ridge terrace should be not less than 1¼ feet high and at least 10 feet broad at the base. Methods of plowing and cultivation should be adopted which will tend to increase the base width from year to year and thus virtually transform the whole field into a series of terraces. (See fig. 2–D.)

Since the stability of a broad-base level-ridge terrace with closed ends depends upon its ability to retain the surface run-off water due to rainfall over the area between it and the next terrace above, it is apparent that the reservoir capacity above the terrace must be sufficient to store this water. Upon this principle are based the following remarks on the design of a system of broad-base level-ridge terraces.

Referring to figure 5, it is seen that the cross-sectional area of the water that can be stored above a terrace is represented by the area *a c b a*. A plan view of the line to which water is backed up before overtopping the terrace is shown in figure 6. A good idea of the size of the reservoir area can be obtained from this plan. Assuming that no water escapes around the ends of the terrace and that no water is lost through percolation into the soil, it follows that for the retention of all of the surface water the area *a c b a* (fig. 5) must be made equal to the product of the depth of the rainfall and the horizontal distance d. If percolation does take place, then the amount of water lost should be deducted from the total amount of rainfall. By equating the amount of surface run-off to the amount of storage above the terrace per unit of length, the following expression is obtained:

$$\frac{dr}{12}=\frac{dh^2}{2v}+\frac{wh}{4}, \text{ or } v=\frac{600h^2+3hws}{100r}$$

where r=surface run-off depth, in inches; h=height of terrace, in feet; w=base width of terrace, in feet; v=vertical distance between terraces, in feet; d=horizontal distance between terraces, in feet; s=slope of land, in feet per hundred, $=\frac{100v}{d}$.

It is assumed that the cross section of the stored water is triangular in shape.

Using the values, h=1.25 feet. and w=10 feet, then

$$v=\frac{9.375+0.375s}{r}$$

Hence, if the values of r and s are known, v, the vertical distance between the terraces, can be computed from the above equation. The value that should be assigned to r depends upon the absorptive capacity of the soil and upon the amount of rainfall for the heaviest single storm. From a general study of the rainfall records for the United States it is found that rainfalls exceeding 8 inches per 48 hours do not occur frequently in a given locality, and it is believed

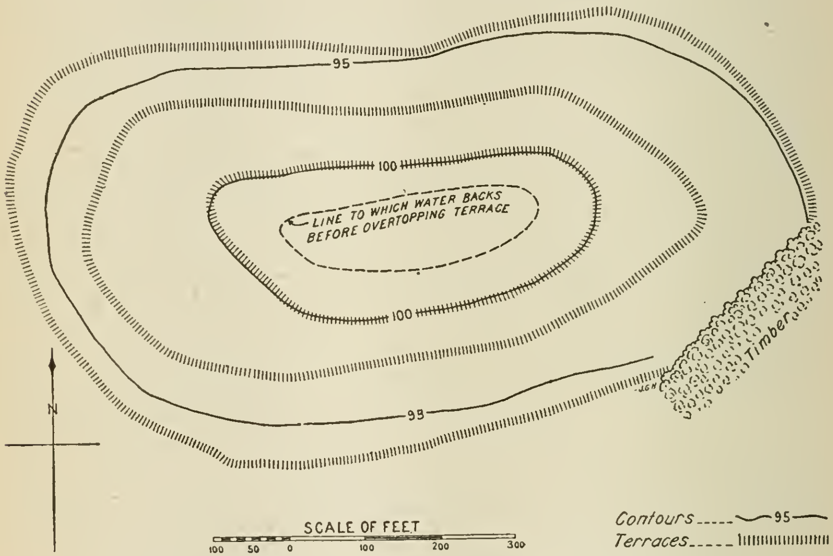


FIG. 6.—Plan of hill protected by broad-base level-ridge terraces.

that provision for 8 inches of rainfall in the design of a system of terraces would give satisfactory results.

By using values of r ranging from 2 inches to 8 inches, depending upon whether a small portion or all of the rain runs off, and using average slopes of land surface of 5, 10, 15, and 20 feet per hundred, a curve for each slope was plotted. (See fig. 7.) The vertical scale on the left of the axis indicates the percentage of an 8-inch rainfall (in 48 hours) that runs off. This percentage depends upon the amount of water absorbed by the soil.

To determine the proper vertical spacing for a system of terraces for any particular field it is necessary to know the average slope of the land surface and the approximate percentage of the rainfall that will percolate into the soil. The former can be measured readily by some form of leveling instrument and the latter can be ascertained by a knowledge of the physical character, the humus content, and the tillage condition of the soil. The susceptibility of the subsoil to the percolation of water also is an important factor to be considered in estimating the run-off.

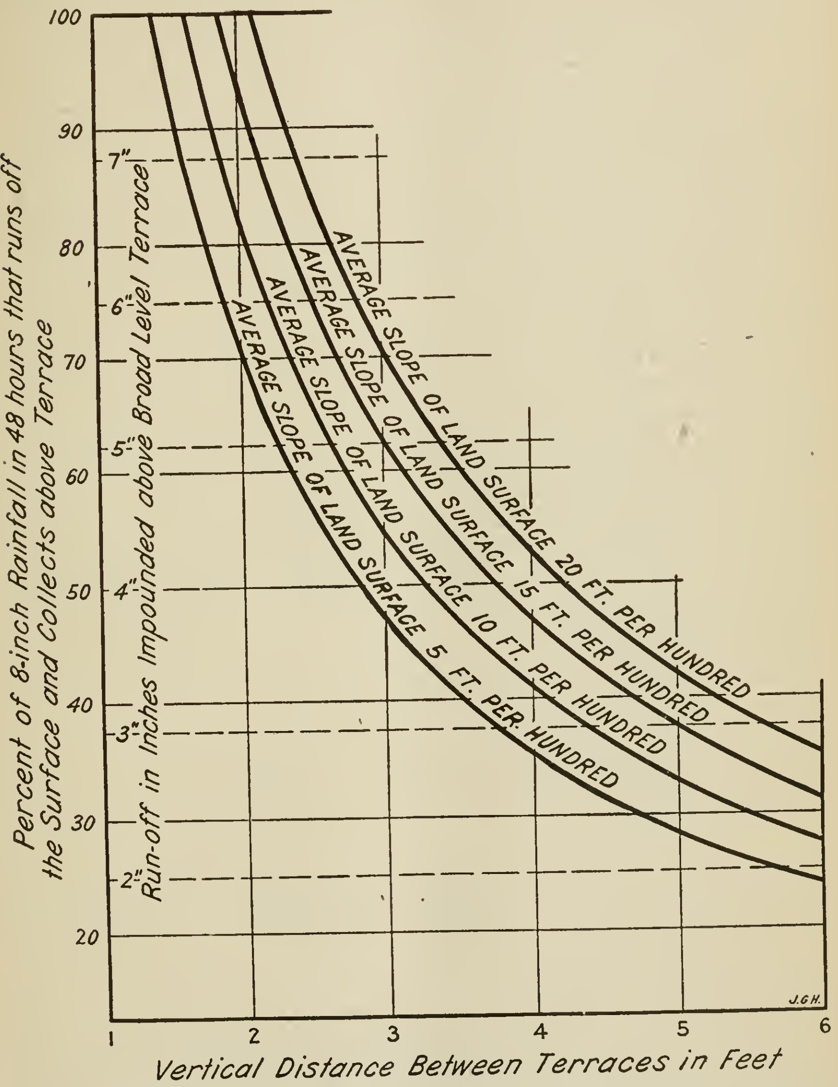


FIG. 7.—Curves showing vertical distances between broad-base level-ridge terraces, for different rates of run-off and land slopes.

It is by no means an easy matter to estimate the percentage of rainfall that will run off for the various types and conditions of soils. For instance, the difference in the rates of percolation for clay and sandy soils is very marked, the latter permitting a much higher rate than the former. This is due to the fineness of the particles and the compact structure of the clay soils as compared with the open, porous structure and coarse particles of the sandy soils. The open structure of a soil facilitates the entrance and rapid circulation of both air and water, since resistance to flow varies inversely as the size of the individual pore spaces. After a long dry period the pores in the upper layers of a soil become filled with air which, until it is expelled, tends to retard the entrance of soil water. A deeply plowed soil will absorb a greater percentage of rainfall than one where shallow plowing is practiced, and the greater the amount of humus in a soil the greater will be its capacity to absorb water. The rate of absorption after the top soil is saturated with water depends upon the permeability of the subsoil. A close, impervious subsoil checks the rate of percolation and thereby increases the run-off at the surface.

The water capacity of the top foot of farm land in good tilth has been stated[1] to be 4 to 5 inches; thus a soil 12 inches deep could absorb this amount of rainfall provided the rain is supplied to the surface at the same rate at which the soil is capable of receiving it. If the former rate is greater than the latter, the excess water runs off over the land surface with a velocity depending upon the slope. The steeper the slope the more rapid the run-off, and correspondingly less would be the time allowed for the absorption of water by the soil. Hence, the steeper the slope the greater will be the percentage of the rainfall flowing off.

To assist in the determination of the percentage of rainfall flowing off from any particular field, the following table was prepared:

Probable percentages of rainfall running off, for the different types of soil, and for a rainfall of 8 inches in 48 hours.

Kind of soil.	Approximate percentage of silt and clay in the soil.	Run-off expressed in percentage of rainfall.							
		Open, pervious subsoil. Slope of land in feet per hundred—				Impervious subsoil.[1] Slope of land in feet per hundred—			
		5	10	15	20	5	10	15	20
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sandy	20	40	45	50	55	45	50	55	60
Sandy loam	40	50	55	60	65	55	60	65	70
Clay loam	60	65	70	75	80	70	75	80	85
Clay	80	80	85	90	95	85	90	95	100

[1] The word impervious should be construed to mean that the subsoil admits water but much more slowly than an open, pervious subsoil.

NOTE.—If soil is deeply plowed and contains much humus, deduct 10 from the above values.

[1] U. S. Geological Survey, Water Supply Paper No. 192, p. 315.

The values in the above table are based upon a field study of the effect of soil and slope upon the run-off. A knowledge of the soil, slope and design of several terraced fields which were known to have withstood heavy rainfall successfully for a number of years furnished data from which was estimated the percentage of rainfall that runs off. These figures were used as a basis for interpolating the intermediate values.

The figures given in the above table are to be used in conjunction with the curves in figure 7 to determine the proper vertical spacing of broad-base level-ridge terraces. For example, if it is proposed to terrace a field having an average fall of about 5 feet per hundred, a pervious subsoil, and a deeply plowed clay-loam topsoil containing considerable humus, then the percentage of water flowing off as taken from the table would be 55. This is found by following the space marked "clay loam" to the right until the column headed 5, "slope of land in feet per hundred," under "pervious subsoil," is reached. The value 65 is found at this point. Now the note below the table specifies that 10 should be deducted from the table values for soil deeply plowed and containing much humus. Hence, the value to be used is 65 minus 10, or 55 per cent. To determine the proper vertical spacing from the curves (fig. 7), extend a horizontal line from the ordinate 55 per cent until it intersects the curve marked 5 feet per hundred, and from the point of intersection project a vertical line to the horizontal axis. Such a line intersects the horizontal axis at about 2.6 feet, which is the required vertical distance between terraces.

Where the average slope of a field is less than 5 per cent, use the vertical spacing as obtained from the 5 per cent curve. For intermediate slopes for which no curve is given, the vertical spacing can be obtained by interpolating between the curves plotted. Where the rate of fall of a field varies down a slope, the vertical spacing may be varied between the terraces to suit the slopes. However, a very small portion of a field often has an excessively steep slope as compared with that of the rest of the field. In such cases the vertical spacing should be chosen to suit the lesser and more general slope of the field. This will place the terraces on the steep slope very close together, but it undoubtedly is the most satisfactory solution of the problem.

It can be seen from the curves in figure 7 that the vertical spacing between terraces decreases as the slope decreases, which precludes the possibility of an excessive slope distance between terraces. This relation minimizes erosion between terraces by reducing both the volume of water and the distance traveled by the run-off water from one terrace to another. The horizontal distance between broad-base level-ridge terraces can be obtained from the curves in figure 4 by adding one-half the vertical distance to the width of the bench for a horizontal-bench terrace.

Were it not for the fact that the terraces would need to be placed very close together on steep slopes, thus necessitating a greater number of terraces, it would be well to reduce the height of the terrace as the slope of the land increases. This would obviate the difficulty encountered in the construction of large terrace embankments on steep slopes.

The equation from which the curves in figure 7 were constructed is based upon the assumption that the ends of the terraces are closed. In the field investigations many terraces with closed ends were found. Some followed contours completely around a knoll or hilltop, forming a closed circuit with no outlet. (See fig. 6.) But most of the level terraces examined had outlets at either one or both ends. In the foregoing discussion the terrace was taken as $1\frac{1}{4}$ feet high; with closed ends it would overflow for a rainfall in excess of 8 inches in 48 hours. However, if one or both ends of a terrace be left open a liberal factor of safety against overflowing is provided. To provide a factor of safety for terraces with closed ends it is recommended that they be made about $1\frac{1}{2}$ feet high.

General discussion.—The success or failure of a broad-base level-ridge terrace depends largely upon whether or not it is laid out on an absolute level. Since the surface of the water stored above the terrace is level, it is imperative that all points along the top of the terrace be above this water level. If one point is low, the water flows over and soon washes away a section of the terrace. All of the water above the terrace then flows toward this crevasse and contributes to the further destruction of the terrace and often erodes a deep gully down through the field. Hence, in laying out a level terrace, the top should be maintained at the same elevation throughout its length.

It is desirable also that the base of the terrace follow the contour of the ground as closely as practicable. This often necessitates the use of very sharp curves and abrupt bends, but it eliminates the existence of any low places or pockets above the terrace which collect and hold water on impervious soil. These sharp bends occur usually at crossings of draws and depressions. Most farmers object to them on account of inconvenience in cultivation and prefer to give the terrace a gradual bend by crossing such places at a lower elevation. Then it is necessary to build the base of the terrace on lower ground and still maintain the top at the same elevation as that of the rest of the terrace, which requires that the terrace be built higher and wider at the base. (See fig. 8.) One landowner who was experienced along this line advised that a terrace crossing a gully or depression be built one-third higher than the required height of the terrace, to provide against subsequent settling. Examinations of a great number of poorly terraced fields showed that breaks occur usually at such crossings, because of the failure to build the terrace to a sufficient height or to the required breadth at the base.

The advantage of crossing a depression at a low elevation lies in the convenience and facility of cultivation. It eliminates the necessity of following around abrupt bends in farming operations. Some objections to it are the initial cost of constructing the large embankment, the impracticability of cultivating such an embankment, the

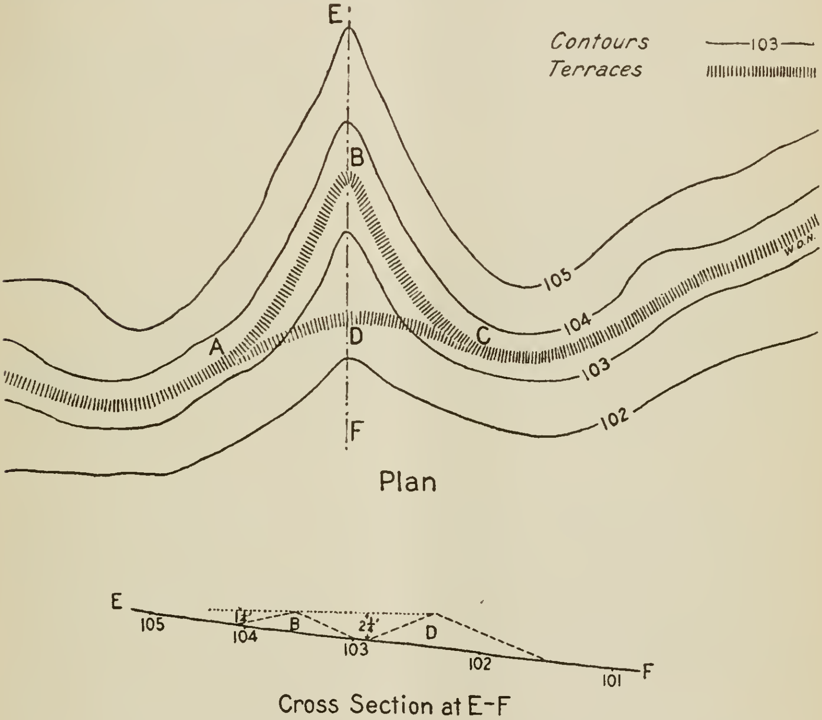


FIG. 8.—Showing two methods of crossing gully. Note height of embankment at D.

extreme susceptibility of this portion of the terrace to failure, and the standing of impounded water above the terrace sufficiently long to injure crops. The disadvantage of the impounded water can be offset by a tile drain laid down the middle of the depression to a natural drainage outlet, and the adoption of this expedient can not be recommended too strongly.

Figure 9 shows a cross section taken down the center line of a depression, or gully, and the method of removing impounded water and retaining sediment by means of a tile drain and drop inlets. If more rapid drainage is desired on a field of level terraces a complete system of tile drains can be installed. The lateral tile drains should be laid along the upper side of the terrace and made to discharge into the main drain laid down the center of the depression or gully. Where stone is available an inlet may be made by filling a section of the trench to within 1 foot of the surface with loose stones. This will facilitate greatly the entrance of the surface water. This practice can be followed also on the tile lines laid down the gully, thus eliminating the objectionable drop inlets which interfere with farm operations. In addition to removing the surface water through the soil and thereby eliminating surface erosion many other benefits result from the practice of tile drainage.

In planning a system of broad-base level-ridge terraces it is desirable, though not necessary, that the terraces end at natural drainage channels. In the absence of such channels they may end at property lines, fence rows, or timbered areas. Cooperative agree-

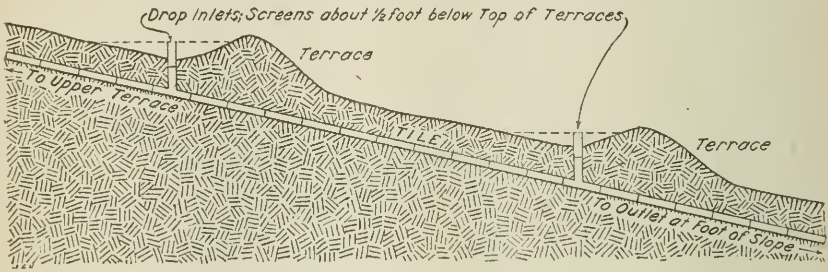


FIG. 9.—Method of removing water impounded behind terraces in a gully.

ments between neighboring landowners for extending a terrace system from one farm to another so that the terraces shall terminate at natural drainage channels would result in increased effectiveness.

Where the system of broad-base level-ridge terracing is employed practically all the fertile particles of soil and the accumulated humus are retained on the surface, and, by proper methods of farming, the fertility of the land is built up from year to year rather than worn out through soil losses. The small amount of soil that moves down the slope, due to such little erosion as takes place between the terraces, can be prevented from accumulating above the terrace by proper methods of plowing and cultivation; that is, by frequently throwing the soil up the slope with the plow and by planting and cultivating the crop rows on level ridges. The result is that each square foot of land surface tends to drink up the maximum amount of the rainfall, and erosive action is thereby reduced to a minimum.

The question arises often as to what becomes of the water above the terrace and whether it remains sufficiently long on the surface to sour the land or injure the growing crop. Experience shows that the natural drainage of open soil on hill lands ordinarily is so rapid that a deficient supply of moisture for crops results and the land is unable to withstand even a moderate period of drought. The broad-base level-ridge terrace tends to correct this by the detention of water above the terrace.

While most upland soils suffer from a lack of moisture, it is true that "worn-out," impervious clay soils with an impermeable subsoil foundation will not permit a ready percolation of surface water. With such soils the rain water would collect on the surface above the terrace, if pockets exist, and remain sufficiently long to injure plant growth. It is essential in such cases that the ends of the terraces be left open; then if the terraces are laid out absolutely level, the water will flow slowly toward the ends by virtue of the higher elevation of the water surface midway the length of the terrace. The subsoil plow or explosives are used sometimes to loosen up the soil above the terrace and thereby increase the amount of percolation. A complete system of tile drainage, as before mentioned, forms a valuable adjunct to a system of level terraces.

The testimony of a number of farmers experienced in the use of the broad-base level-ridge terrace is, that in dry seasons or periods of drought they obtained the best crop yields from level-terraced fields as compared with adjacent unterraced and graded-terraced lands, and that their crops were equally good in seasons of abundant rainfall.

The broad-base level-ridge terrace is best adapted for use on open, pervious soils and on slopes up to 15 per cent. But it can be used successfully on any type of soil if the vertical spacings are as shown by the curves in figure 7 and means are employed to remove any surface water which may collect in depressions above the terrace. This terrace is used often on slopes steeper than 15 per cent, where such slopes occur in portions of fields having a smaller average slope. Wherever used, it is vitally important that proper methods be employed and care exercised in the laying out, construction, and maintenance of the terrace system.

THE GRADED-RIDGE TERRACE.

The narrow-base form.—Like the level terraces, the first graded terraces were small, with narrow bases, and the terrace embankments were seeded to grass or allowed to grow up in weeds to protect the terrace against erosion due to the flow of the water above. The narrow-base graded-ridge terrace is built usually from 3 to 6 feet wide at the base and from one-half to 1 foot high, with a fall of one-half foot to 2 feet in the 100. Some objections to this terrace are, the necessity of growing a protective covering on the terrace, the erosion along the upper side of the terrace due to the flowing water and the failure of the small terrace embankments to withstand the water pressure above or the effects of erosion due to overtopping.

If the terrace has a fall greater than one-half foot per 100 feet, erosion occurs above the terrace, a channel is scoured out and it develops practically into a hillside ditch. Although this type of terrace is used extensively in the Piedmont region of the South, it is being supplanted rapidly by forms of the broad, cultivated terrace.

The broad-base form.—The broad-base graded terrace, generally known as the Mangum terrace, has been adopted in many sections of the country for the reason that the entire terrace bank can be cultivated—thus utilizing all land and preventing growth of objectionable weeds and grass. This terrace can be crossed readily at any angle in planting and cultivating crops with large farm machinery. When it is intended to use such machinery and to cross at an angle, the terrace must be made broader than when all farming operations are in lines parallel with the terrace. The following tabulated values are the results of surveys of terraced fields of the Mangum type near Wake Forest, N. C.:

Actual dimensions of Mangum broad-base graded terraces.

Dimension.	Absolute minimum.	Absolute maximum.	Field averages.	
			Minimum.	Maximum.
Base width of terrace.....feet..	25	50	30	33
Height of terrace.....feet..	.3	1	.5	.6
Vertical distance between terraces.....feet..	2	8.9	2.8	7.7
Length of terrace.....feet..	450	1,250	.....	.....
Grade of terrace.....per cent..	1.69	2.24	2	2.1
Slope of land surface.....per cent..	4.7	18.2	5	14

These fields appeared as series of broad waves. On the steepest slopes, where one terrace slope ends the next one begins, the whole field being a succession of terraces. (See fig. 2, E and F.) The rows were run parallel with the terraces shown in figure 2 E; on a less steep slope (fig. 2 F) the rows crossed the terraces.

Surveys were made also of a number of fields with graded terraces where the crop rows always were parallel with the terraces. The results obtained are shown in the following table:

Actual dimensions of broad-base terraces where rows are parallel with terraces.

Dimension.	Absolute minimum.	Absolute maximum.	Field averages.	
			Minimum.	Maximum.
Base width of terrace.....feet..	5.2	19	7.8	15.5
Height of terrace.....feet..	.4	1.8	.7	1.1
Vertical distance between terraces.....feet..	2	9.2	2.9	8.3
Length of terrace.....feet..	200	1,800	.....	.....
Grade of terrace.....per cent..	.1	2.24	.3	2
Slope of land surface.....per cent..	3.4	20	4.4	14

The width and height of old terraces depend upon their size at the time of construction and methods of plowing employed to maintain them. As a rule terraces that are tended properly grow broader with age and diminish in effective height, so that what is lost in height and diminished size of water channel is gained in broadness, and generally in an increased absorptive capacity of the soil. Graded terraces should be built originally about 10 feet broad at the base and about $1\frac{1}{4}$ feet high and should be thrown up each year with a plow until they acquire gradually a cross section similar to those shown in figure 2–F.

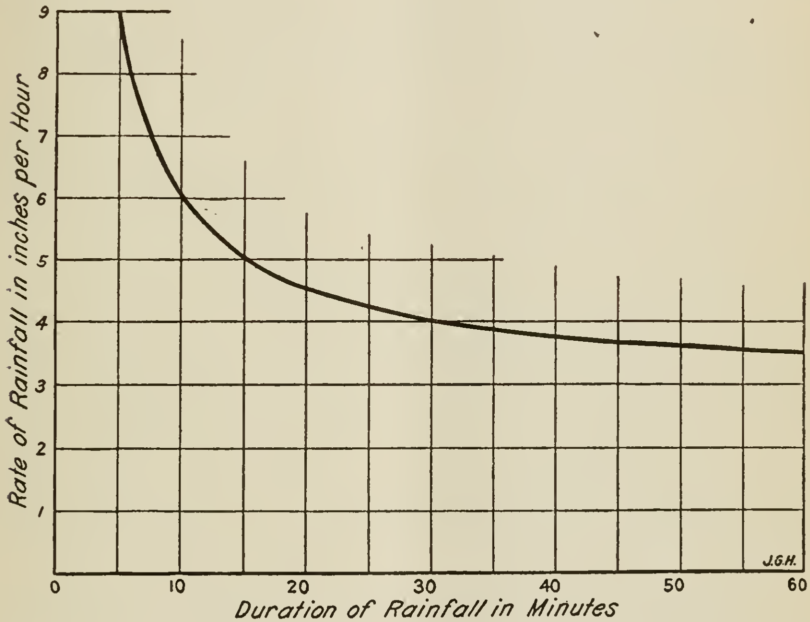


FIG. 10.—Rates of rainfall for short periods, for which graded terraces should be designed.

The principle involved in the design of a graded terrace is that the channel above the terrace be made of such a size and grade that it will conduct the surface water slowly to a drainage outlet without the possibility of the water overtopping the terrace. Hence, it is necessary to know something of the rates and duration of the rainfall which is the source of the surface water.

A study was made of rainfall intensities for short periods, as shown by the Weather Bureau records for the humid portions of the United States, and a curve (fig. 10) was plotted which is thought to represent closely the rates of rainfall for short periods that should be provided for in the design of a system of graded terraces. The records show that these rates sometimes will be exceeded, but not so frequently in any given locality as to warrant greater rates being used. Referring to the curve, the horizontal scale represents the durations of rainfall in minutes and the vertical scale the rates of rainfall in inches per hour. For example, from the curve the rate of rainfall for a rain lasting 30 minutes would be 4 inches per hour, and one of 5 minutes 9 inches per hour. The equation for this curve is:

$$y=\frac{30}{x}+3$$

where y = rate of rainfall in inches per hour, and x = duration of rainfall in minutes.

To determine the rate of discharge to be provided for in the design of a terrace system, the so-called rational method of computing run-off is employed. According to this method the maximum discharge will take place when water from the most remote point of the drainage area above the terrace reaches the terrace outlet, provided the rate of rainfall continue uniform for a period equal to that required for water to travel from the upper to the lower end of the drainage area. Hence if the length and grade of the terrace be known and the average velocity of flow be computed, the time interval can be obtained readily. For instance, if the time interval is found to be 30 minutes, then the maximum rate of rainfall to be expected would, from the curve, be 4 inches per hour. In computing this time interval the distance from the upper to the lower end of the drainage area is taken as being equal to the length of the terrace, the distance between terraces being disregarded. This practice results in the use of a little larger rate of run-off than would apply if the distance between terraces were included and therefore is on the side of safety. Furthermore, the velocity at the lower end of the terrace, instead of the average velocity along the terrace, was used in computing the time interval which likewise would result in the use of a little larger rate of run-off.

Terraces with uniform grade.—Field examinations of a great many graded terraces show that erosion of average soils takes place where the grade of the terrace exceeds 0.5 foot per 100 feet. Even at this grade some of the fine particles of soil are carried away in the run-off water. Many advocates of the graded terrace favor the use of a grade not to exceed 0.5 per cent. The following values were used in the computations for the curves discussed hereafter: Base width of terrace, 10 feet; height of terrace, $1\frac{1}{4}$ feet; depth of flow, $\frac{3}{4}$ foot; and value of "n" in Kutter's formula, 0.035. Using the velocity computed by the formula, $v=c\sqrt{rs}$, where c is the constant determined from Kutter's formula, r the hydraulic radius, and s the slope, the time intervals were determined for terraces ranging in length from 300 to 1,800 feet. The corresponding rates of rainfall were obtained for these time intervals from the rainfall curve in figure 10; these are the rates of run-off that would obtain at the lower ends of the terraces, assuming all the rainfall to run off. With the above data the required vertical distances between terraces of different lengths were computed and the curves in figure 11 plotted. Two factors of safety are included in the above computations, (1) the depth of flow is made only $\frac{3}{4}$ foot, whereas the terrace is built $1\frac{1}{4}$ feet high, and (2) all of the rainfall is assumed to run off, whereas a portion of it would percolate into the soil. Experience shows that a wide margin of safety is most desirable owing to the piling up of the water due to obstructions or abrupt bends, and to possible variations in the height of the terrace and in the grade.

To illustrate the use of the curves in figure 11, suppose it is desired to determine the proper vertical spacing on a field with a slope of 15

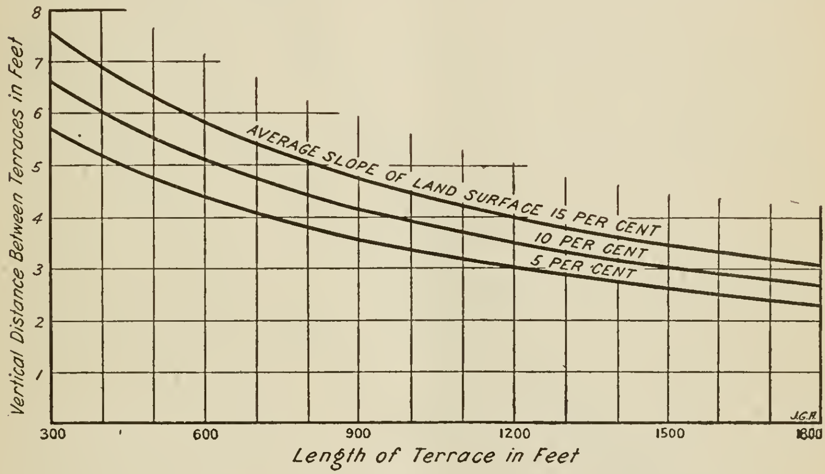


FIG. 11.—Uniform-graded terraces, for grade of 0.5 per cent. Curves showing required vertical distances between terraces for different land slopes and terrace lengths.

per cent for terraces 600, 700, 800, and 900 feet in length. Referring to the curve marked 15 per cent in figure 11, it is seen that the proper vertical spacings for terraces of these lengths are about 5.8, 5.4, 5.1, and 4.7 feet, respectively. It will be seen from the curves that the longer the terrace the less must be the vertical spacing. Owing to this fact and to the greater likelihood of breaks in a long terrace, it is advisable to make the terraces as short as the governing conditions will permit. Where an adequate outlet is available at both ends of the terrace, they should be utilized by giving fall to the terrace from about the middle toward each end. For terraces less than 300 feet in length the same vertical spacing should be used as is given by the curves for 300 feet.

If it is desired to maintain the same vertical spacing for all lengths of graded terraces, it becomes necessary to increase the grade for the longer terraces, since the drainage area increases with the length of the terrace while the cross-sectional area of the channel remains constant. Field observations show that spacings of 3, 4, and 5 feet give the most satisfactory results on slopes of 5, 10, and 15 per cent, respectively. Using these data, the three curves in figure 12 were plotted. It can be seen from these curves that for a given vertical spacing and land slope, the grade required increases rapidly as the length of the terrace increases, and if it were not desired to use

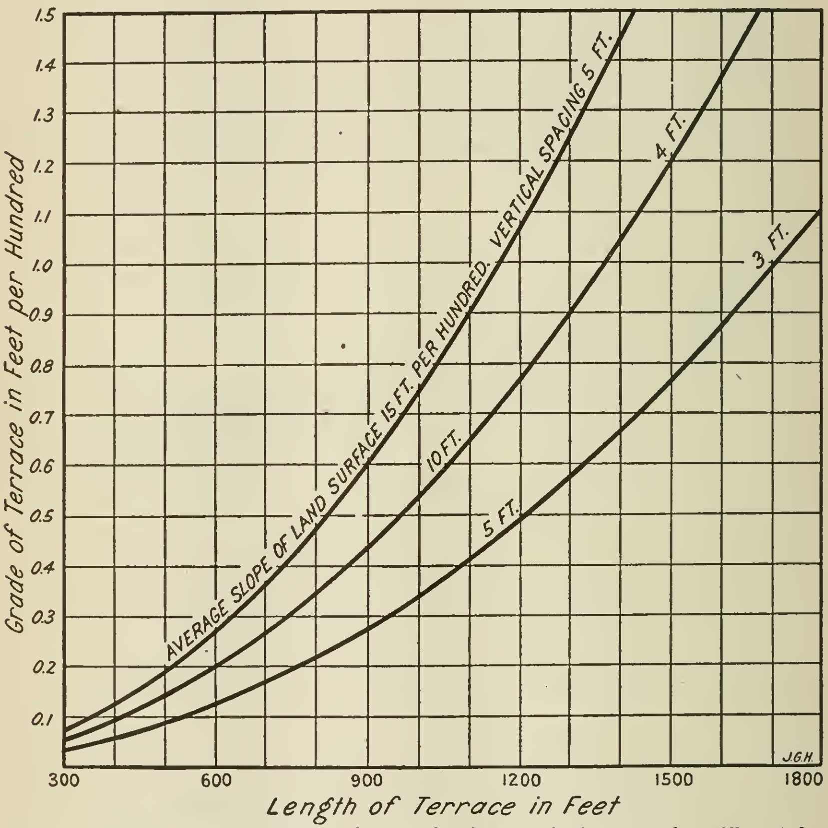


FIG. 12.—Uniform-graded terraces. Curves showing required grades for different land slopes, terrace lengths, and vertical spacings.

a grade greater than 0.5 per cent the lengths of the terraces on the 5, 10, and 15 per cent slopes would be limited to 1,210, 970, and 820 feet, respectively. The curves show also that terraces up to 300 feet in length require very little grade. A terrace of only 300 feet requires practically no grade on any type of soil, because a sufficient grade will be created by the distribution of water above the terrace to cause a flow toward the ends. Other things being equal, the most efficient terracing is found where comparatively short terraces and low grades exist.

For this type of terrace it would not be necessary to maintain the same size of embankment throughout the length of the terrace, but the embankment could be reduced as the upper end is approached. The channel capacity required, which depends upon the drainage area above, decreases toward the upper end of a uniform graded terrace.

Terraces with variable grade.—Surveys were made of several fields with graded terraces where the grades were found to vary. These were in better condition than were any having uniform-graded terraces. The profiles of the grade lines of these terraces showed a tendency of the grade to increase toward the outlets, a short distance at the upper end of the terrace being level. This practice possesses much merit. The grade is increased at intervals along the terrace to accommodate the continually augmented discharge from the increasing size of the drainage area. A lesser grade may be used at the lower end of a variable-graded terrace than is required for a uniform-graded terrace of the same length. This is due to the fact that a smaller rate of rainfall can be used, since with the lesser grade of the variable-graded terrace, the time required for the water to flow the length of the terrace is greater than for the uniform-graded terrace.

In figure 13 are shown curves for terraces with variable grades, similar to the ones in figure 12 for terraces with uniform grades. It can be seen from the curves that the lengths of a variable-graded terrace that can be used, for a grade of 0.5 per cent at the lower end, are 1,570, 1,280, and 1,100 feet on slopes of 5, 10, and 15 per cent, respectively, as compared with lengths of 1,210, 970, and 820 feet for terraces with a uniform grade of 0.5 per cent.

In laying off a terrace with variable grade, the grade should be increased at intervals of 200 or 300 feet and at all sharp bends where the terrace crosses a gully or depression in a field. For example, if it is desired to lay off a terrace on a 10 per cent slope, 1,200 feet long and with a vertical spacing of 4 feet, and the grade of the terrace is to be changed every 300 feet, then from the curves in figure 13 the grades would be as follows:

Station.		Grade in feet per 100 feet.
From—	To—	
0	300	0.05
300	600	.14
600	900	.27
900	1,200	.45

It is seen from the above that the grade for the first 300 feet of terrace is almost negligible. This portion could well be laid off level. If a terrace with a uniform grade were used, the curve in figure 12 shows that a grade of 0.77 per cent would be required. Both practice and theory show that the variable-graded terrace is superior to the uniform-graded type.

Outlets.—Wherever possible terraces should end at natural drainage channels. The absence of a suitable drainage outlet within the limits of a field often necessitates ending the terraces at fence lines, depressions or draws. The volume of water which is discharged from the ends of a system of graded terraces often erodes unsightly and objectionable ditches along the ends of the terraces to the foot

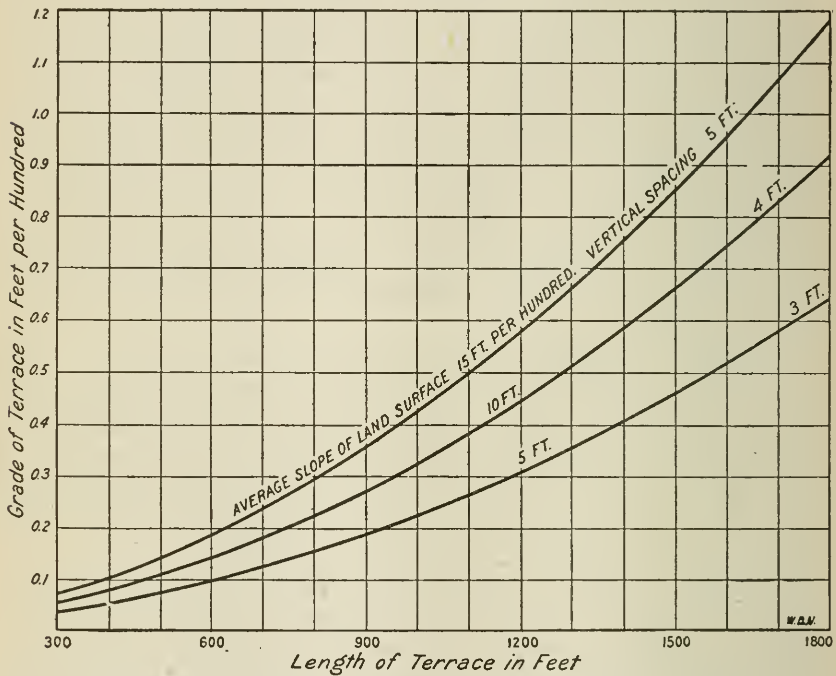


FIG. 13.—Variable-graded terraces. Curves showing required grades for different land slopes, terrace lengths, and vertical spacings.

of the slope. Erosion in such channels can be reduced greatly by lining them with stones or seeding them to grass (see Plate V, fig. 2). The channels and banks of graded terraces should not be cultivated for 20 to 30 feet from the outlet channel but should be permanently sodded. Breaks commonly occur and erosion is most active near the ends of graded terraces, owing to the usually large volume of water passing. Some sort of protective covering of stones, boards or other hard material should be employed to prevent this washing. Where a terrace discharges into a deep ditch a box trough is used sometimes to give the water a free overfall into the ditch. This prevents erosion in the terrace channel.

D659

FIG. 1.—VIEW SHOWING GRADED TERRACE WASHING BADLY DUE TO EROSIVE ACTION OF WATER.

D187

FIG. 2.—TERRACE DRAG WITH METAL CUTTING EDGE FOR BUILDING UP TERRACES.

D191

FIG. 1.—TERRACE DRAG (LONG SIDE HINGED) FOR BUILDING UP TERRACES.

D658

FIG. 2.—GRADED TERRACE CONSTRUCTED WITH PLOW AND SCRAPER.

Sometimes hillside ditches are constructed as outlets for terraces. Such ditches should have a fall two or three times that of the terraces and should be located so as to cross them and discharge into the nearest available drainage channel. Often wooded strips of land are left in fields to afford a place for the discharge of the water with a minimum amount of erosion.

General discussion.—Many of the failures of graded terraces may be attributed to irregularities in grade. Breaks occur often with abrupt reductions in the grade. This causes a piling up of the water, and a consequent overtopping of the terrace by reason of the inability of a full channel to carry the same amount of water on a light grade as on a heavy one. With a variable-graded terrace there is less likelihood of overtopping because the grade is increased at short intervals along the terrace.

Again, breaks in graded terraces are very frequent where gullies and depressions are crossed and at abrupt bends. Such breaks are due to sudden changes in the direction of flow or to a change in grade, and often to both. The usual practice of crossing depressions at a low elevation to avoid abrupt bends, as explained under "The broad-base level-ridge terrace," results in an increase of grade to the middle of the depression and a decrease beyond the middle. In order to avoid a break due to this diminution in grade it becomes necessary to maintain the top of the terrace at a uniform grade. This necessitates the building of a high and broad embankment across the depression similar to the one described for level terraces. Wherever it can be done without increasing the grade to such an extent as to cause serious erosion, it is advisable to make the grade greater for that portion of the terrace leading away from the middle of the depression than for the portion leading to the middle.

The graded terrace is adapted particularly for use on impervious and worn-out soils, and on shallow open soils with an impermeable subsoil foundation—in general, soils that are incapable of absorbing much water. Since the object of terracing is to prevent erosion, and as this is accomplished best by securing the least movement of the surface water, it can be seen readily that, within limits, the efficiency of a graded terrace varies inversely with the amount of fall given to it. The greater the fall the greater the velocity and, hence, the greater the erosive power of the moving water.

The embankment of a graded terrace, being subjected to the erosive action of the water on its upper side, is often washed considerably, particularly at bends. Plate VI, fig. 1, shows a graded terrace embankment cut away practically half by erosion and the heavier parts of the soil deposited along the upper side of the terrace. The deposit of soil in the terrace channel reduces both the grade and the cross-sectional area of the channel and renders the terrace extremely susceptible to overtopping during the next rain. Also the finer, lighter, and more fertile particles of soil remain suspended in the moving water and are carried off the field. In such cases, by the use of excessive grades, the very cream of the soil is lost. Where erosion of a terrace takes place no attempt should be made to cultivate the terrace. It should be seeded to grass.

COMPARISON OF TERRACE TYPES.

In order to show the relative merits of the bench terrace and the various forms of broad-base ridge terraces, the table below was prepared. Under the column headed "Least amount of erosion" is found the broad-base level-ridge terrace ranking first and the uniform-graded terrace last. Since the primary object of terracing is to reduce erosion, this advantage should have the greatest weight when considering the merits of the different types. The broad-ridge terrace is much superior to the bench type of terrace when considering the "Least waste land or weeds." The embankment of broad-ridge terraces can be cultivated successfully and hence no land is lost to cultivation or weeds allowed to grow on the terrace.

Showing how terraces rank with respect to various advantages.

Type of terrace.	Least amount of erosion.	Least waste land or weeds.	Fewest terraces required in field.	Ease of cultivating land.	Best adapted to— Pervious soils.[1]	Impervious soils.	Steep slopes.	Best land builder.
Horizontal and sloping bench	2	2	3	2	2	3	1	2
Broad-base level ridge	1	1	3	1	1	4	4	1
Broad-base uniform-graded ridge	4	1	2	1	4	2	3	4
Broad-base variable-graded ridge	3	1	1	1	3	1	2	3

[1] With reference to least amount of erosion.

Under the column headed "Fewest terraces required in field," the graded terrace ranks ahead of the level type owing to the fact that by giving the terraces considerable fall they may be spaced farther apart than level terraces. However, the greater vertical spacing can be used only at a cost of greater erosion to the field.

Broad-terraced fields are easier to cultivate than the bench type since implements and large machinery can be moved across the broad terraces and if desirable the rows can be run at any angle. With the bench type each bench must be cultivated separately, and difficulty is encountered in getting implements from one bench to another.

From the standpoint of erosion the broad-base level-ridge terrace is best adapted for use on pervious soils; on impervious soils the graded terrace can be used to the best advantage since in the former case most of the water is drained off through the soil and in the latter the water is drained off the field over the surface.

The bench terrace is best adapted for use on steep slopes where it would be practically impossible to build and cultivate a broad-ridge terrace.

The broad-base level-ridge terrace contributes to the building up of land possibly more than does any other form. With this terrace practically no fertile parts of the soil are allowed to escape from the field. The bench terrace also is a good land builder. The greatest objection to the use of the graded terrace is that the water drained off the field usually carries in suspension fertile particles of the soil.

The table below was prepared to assist in the selection of the terrace best adapted to the needs of a particular field. In this connection it is recommended that the design of the terrace system be made from the curves as given in this paper for each type of terrace.

Types of terraces most applicable to land of various slopes.

Kind of terrace.	Average slope of land.	Type of soil.	Grade of terrace.
	Per cent.		
Horizontal and sloping bench	15 to 20	Fairly pervious.	Level.
Broad-base level ridge	3 to 15	...do	Do.
Broad-base graded ridge	3 to 15	Impervious, worn out.	Preferably variable, 0.0 to 0.5 per cent.[1]
Broad-base level ridge with tile drainage	3 to 15	Any type	Level.

[1] Grade will depend upon the length of the terrace, but it is advisable not to exceed a grade of 0.5 per cent if possible.

On the steeper slopes, where the soil erodes easily, clean-cultivated crops, such as cotton and corn, should not be grown. Impervious soils on slopes of 15 per cent or more, and all soils on slopes of more than 20 per cent, are best suited to pasture and timber.

The result that should be attained by a system of terraces and proper farming methods is well expressed in the following quotation taken from a bulletin[1] on Soil Erosion by W J McGee, of the Bureau of Soils, United States Department of Agriculture:

> The primary object is conservation of both solid and fluid parts of the soil through a balanced distribution of the water supply. The ideal distribution is attained when all the rainfall or melting snow is absorbed by the ground or its cover, leaving none to run off over the surface of the field or pasture; in which case the water so absorbed is retained in the soil and subsoil until utilized largely or wholly in the making of useful crops while any excess either remains in the deeper subsoil and rocks as ground water or through seepage feeds the permanent streams.

The above conditions are fulfilled most nearly by the horizontal bench terrace and the broad-base level-ridge terrace, since the movement of the water is reduced to a minimum by both. The graded terrace lacks much in meeting the requirements. The broad-base

[1] U. S. Dept. of Agr., Bureau of Soils, Bulletin 71, p. 56.

level-ridge terrace possesses a decided advantage over the horizontal bench terrace with respect to the elimination of weeds and waste land, and over the graded terrace with reference to the movement of the surface water.

In view of the above discussion it is recommended that the broad-base level-ridge terrace be used wherever conditions of soil and topography will permit—that is, where the soil absorbs a portion of the rainfall and the slopes are not too steep. The broad-base level-ridge terrace supplemented by efficient tile drains suitably located would afford the most ideal method for preventing soil erosion on any type of soil. Often the yields obtained and the saving resulting from the absence of soil erosion would justify, in a financial way, the installation of tile.

LAYING OFF A TERRACE SYSTEM.

The courses to be followed by the terrace lines are governed by the topography of the field. This is well illustrated in figures 14 to 16. Where the slope of a field is practically uniform and in one direction (fig. 14) the terrace lines will be straighter and more regular than where the slopes vary much in amount and direction (figs. 15 and 16). Figures 14 and 15 show fields having broad-base level-ridge terraces. It will be noted that the terraces follow approximately the contours of the ground. Figure 16 illustrates a field of broad-base graded-ridge terraces. In this case the terraces are seen to cross the contours.

It must be remembered that a terrace is designed to provide for the run-off water from a limited area above it and when this area is exceeded the stability of the terrace is endangered. A very common cause of failure of terrace systems is the fact that the upper terrace in the field is made to drain an excessive area. As a result, the upper terrace breaks, and a large volume of water rushes down the slope, breaking all terraces below. Frequently a farmer desires to terrace his farm but his neighbor's farm lies at a higher elevation and the upper terrace would be required to handle run-off water from his neighbor's land. In such cases an attempt should be made to induce the neighbor to terrace his farm also. If this can not be done the water from above must be intercepted by means of a hillside ditch to carry the water to the nearest drainage channel below.

The success or failure of a terrace system is largely a matter of proper laying off of terrace lines. Various kinds of homemade devices are employed for laying off terraces, but unless the operator exercises special care in the use of them the results usually are poor. Many landowners realize the inefficiency of these devices and have adopted as a substitute a cheap form of telescopic spirit level mounted on a tripod. Even with this level, in the hands of an inexperienced or careless operator, the results obtained are far from satisfactory. Surveys of seven level-terraced fields where a level of the above type was used showed an average variation in level along the terraces for each field ranging from 0.4 to 2.6 feet. The engineer's Y level is by far the most satisfactory instrument for this work and the results obtained warrant the small expense of employing a competent engineer or surveyor who has such an instrument. A number of surveys of terraced fields laid off with an engineer's level in the hands of experienced levelmen showed remarkably little variation from the level or uniform grade line.

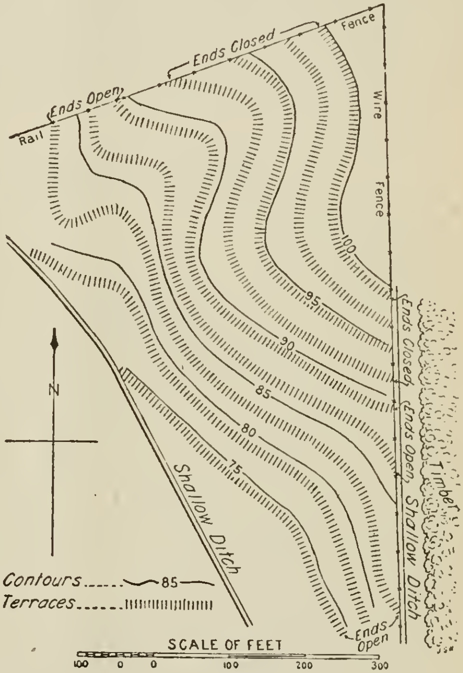


FIG. 14.—System of level-ridge terraces on a field having regular slopes.

Laying off level-terrace lines is a simple leveling proposition which consists merely of following contours of the field with a chosen vertical interval between them. The terrace nearest the top of the field should be laid off first. The level instrument should be set in a position near the middle of the terrace line so as to command a view of the whole length of the terrace, and sufficiently high so that the bottom of the rod, when set at the highest point in the field, is slightly below the level line of sight of the instrument. If, for instance, the reading observed on the rod at the highest point be 0.5 foot and the vertical distance between terraces is to be 3 feet, the rod is placed at a point directly down the slope where the rod reading is 3.5 feet. To establish the line of the terrace, points of equal elevation should then be located to both ends of the terrace at intervals of 25 to 50 feet, the closer spacing being used for land of irregular topography. Invariably a point should be established where the terrace line crosses a draw, gully, or depression. The points established may be marked permanently by stakes to be used subsequently as guides in the construction of the terrace. A very common method is to lay out and construct the terrace at the same time, or at least to plow one furrow to establish definitely the line of the terrace. In this method the rodman is followed by a man with a hoe who digs a hole at each position of the rod to serve as guides to the plowman who follows immediately and lays out the first furrow. This is the cheapest and most satisfactory method of laying out level terraces.

Several terraces may be laid out from one position of the instrument, depending upon the vertical interval and length of the rod. If the entire length of the terrace can not be seen from one position of the level, the rodman should retain the rod at the last point visible, the instrument should be moved to a new position, and a reading of the rod taken. This reading should be used in locating points on the terrace line from the new position of the instrument.

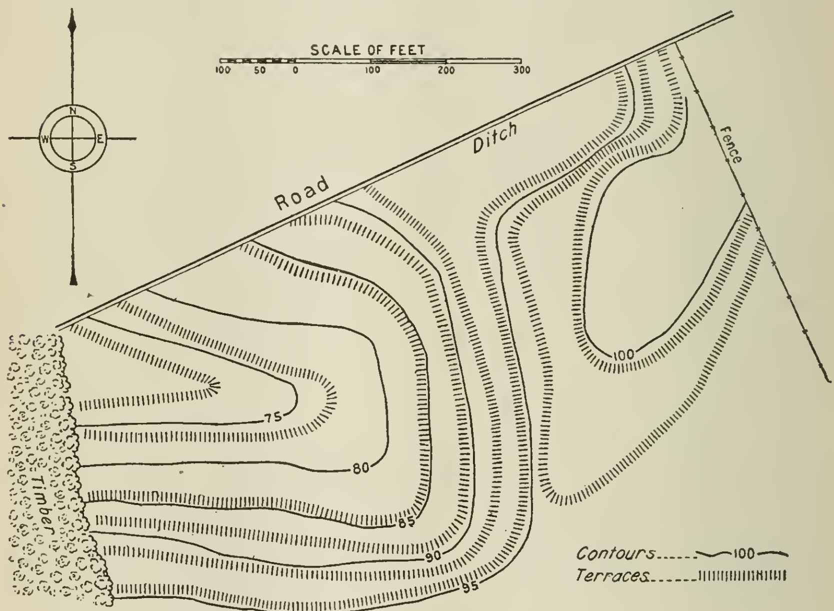


Fig. 15.—System of level-ridge terraces on a field having irregular slopes.

The graded terrace is more difficult to lay out than is the level terrace, because the rod readings never are the same for any two points on the terrace line. The first point on the terrace line is found in a manner similar to that described for the level terrace. Assuming that the terrace drains to one outlet, then a fall will occur from the middle of the terrace line toward the outlet and a rise in the other direction. If, for instance, a grade of 0.4 foot per hundred feet be used, and if guide stakes are to be set 50 feet apart where the alignment is fairly straight and 25 feet apart on bends, then for each 25 feet in distance toward the outlet a fall of 0.1 foot would be required, and, therefore, for each 25 feet in the direction of the outlet the rod reading should be increased 0.1 foot. The distance should be measured with a tape. If a variable grade is used the rod readings should be computed accordingly.

No attempt is made to give comprehensive instructions for laying out terraces since different topographical conditions will suggest different methods of procedure to the levelman of good judgment and experience. The best results are obtained with a good leveling instrument in the hands of a careful, competent, and experienced levelman.

CONSTRUCTION OF TERRACES.

All types of terraces are constructed originally in the same way. The work of construction should begin invariably with the highest terrace in the field and each terrace should be completed before work

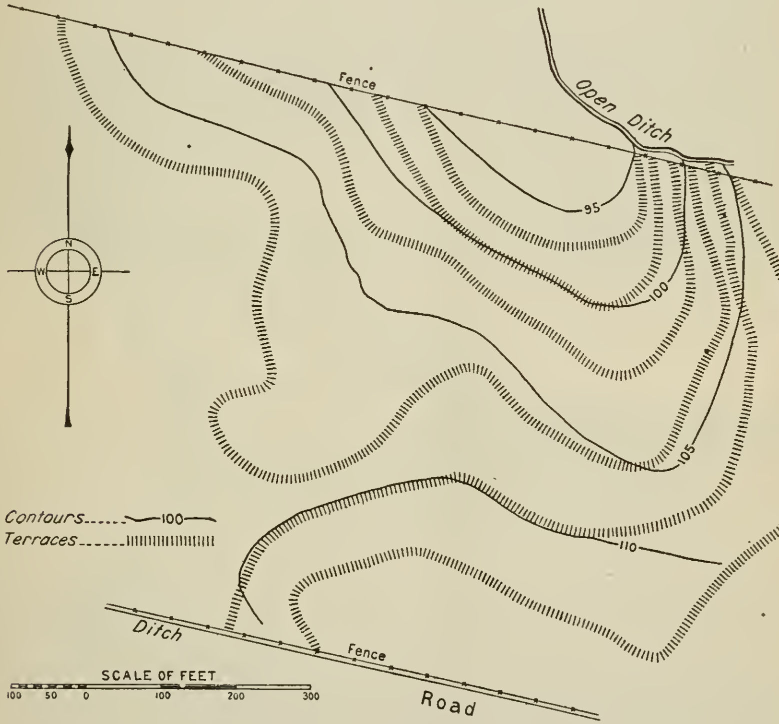


FIG. 16.—Field of graded-ridge terraces.

is started on the one next below. The late fall and early winter is the best time to lay out and build terraces. If one has not time to terrace his whole field well it is better to construct well the first few terraces near the upper side of the field than to terrace the whole field poorly, for a break in a terrace near the upper side of the field is followed by breaks in all below.

The terrace embankment can be built up wholly with an ordinary turning plow. A large sixteen-inch plow with an extra large wing attached to the moldboard for elevating the dirt, is an effective implement for throwing up a high terrace bank. For broad terraces furrows are thrown toward the center line from each side for a strip

15 to 20 feet in width. Then, commencing at the center again, the strip is plowed in the same manner as before. This procedure is repeated until the terrace has reached the desired height. Many farmers allow the loose earth to be settled by a rain between plowings so that the dirt will turn better. However, it is safer to build the terrace to the desired height at the start for, if a heavy rain, sufficient to overtop the terrace, comes between plowings, much of the original work is undone and considerable damage occurs from erosion. A disk plow can be used successfully to throw up loose dirt, and the ordinary road grader is employed often and is adapted especially to such work.

The most commonly used and cheapest implement for throwing up a terrace is a wooden, V-shaped drag. Plate VI, figure 2, and Plate VII, figure 1, show two terrace drags that have been used satisfactorily. Figure 17 shows a terrace drag with dimensions.

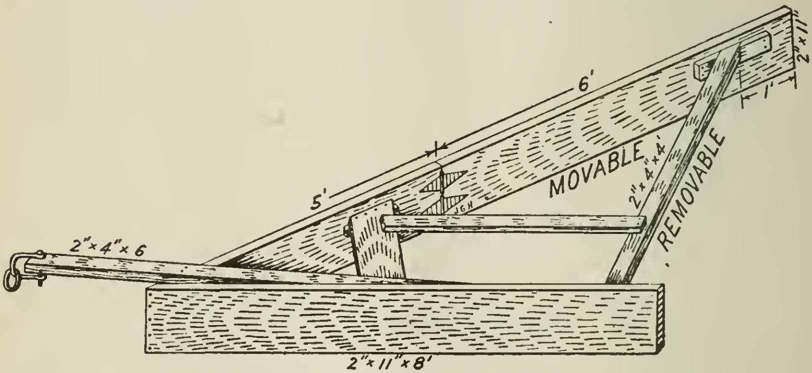


Fig. 17.—A terrace drag.

After the first three or four furrows have been plowed on each side of the center line of the terrace, the drag is used to push the loose earth toward the center and thus build the terrace higher. The plowing is resumed and the drag used again, and this is done repeatedly until the terrace has attained the desired width. If the terrace is not built sufficiently high the first time, the work is started again at the center and the plowing and dragging are repeated. The longer side of the drag is hinged so that for the first few furrows the hinged portion is allowed to swing loose. As the terrace increases in width, and it is desired to move the loose earth a greater distance, the removable brace is set in position and the hinged portion is brought into use. The short side of the drag is made to follow the open furrow; this holds the drag in the proper position. The piece to which the hitch is made should be set at a vertical angle with the shorter side, as shown in figure 17, and also at a horizontal angle, as shown in Plate VII, figure 1. The former tends to keep the short side parallel with the bottom of the furrow and the latter

D601

FIG. 1.—ROW OF COTTON ON TOP OF BROAD-BASE LEVEL-RIDGE TERRACE.

D602

FIG. 2.—THREE ROWS OF COTTON ON BROAD-BASE LEVEL-RIDGE TERRACE.

D134

FIG. 1.—BADLY ERODED LAND NEAR HOLLY SPRINGS, MISS., THAT WAS MADE TO PRODUCE CROPS.

D182

FIG. 2.—DAM-AND-POND METHOD OF RECLAIMING GULLIES.

keeps the point pressing slightly against the edge of the furrow and prevents a tendency of the drag to jump out.

Graded terraces commonly are built with a plow and drag scraper. A strip is plowed, as heretofore described, and the loose earth on the upper half of the strip is scraped up and deposited on the lower half. By this method a channel is constructed for the flow of the water, and the earth used to build up the embankment. (See Pl. VII, fig. 2.)

MAINTENANCE AND CULTIVATION OF TERRACES.

A newly built terrace is susceptible to failure until it becomes thoroughly settled. For this reason it is not advisable to cultivate the terrace the first year. It should be sown to some sort of cover crop. Breaks in terraces in the first year tend to discourage a novice in the use of terraces, but unless the embankment is built to an abnormally large size breaks occur often in newly made terraces.

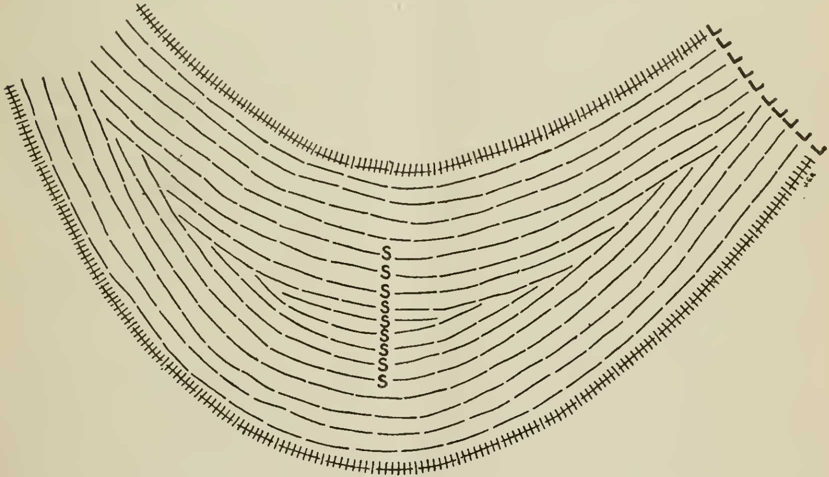


FIG. 18.—Method of laying out rows where distance between terraces varies (L, long rows; S, short rows).

After the terrace has been established permanently, the soil should be thrown toward the center at each plowing of the field, at least once a year. This will increase the breadth and maintain the height of the terrace and the field eventually will assume an appearance of a succession of prominent waves, all of which may be cultivated easily. (See fig. 2–D, E, and F.)

In cultivating a terrace as much of the soil as possible should be thrown toward its center. The best results are obtained where the rows are run parallel with the terraces. At first, usually one row is planted on the top (Pl. VIII, fig. 1), but as the terrace grows broader several rows are planted as shown in Plate VIII, figure 2. These rows invariably produce a greater yield than do those on the land between the terraces. Where large machinery is used, and it is difficult to follow the terrace line, the rows may be run at an angle across the terraces, where the land is not very steep, as in figure 2–F. To do this the terraces must be broad and must be thrown up at least once a year to maintain their height.

Where the rows between two adjacent terraces are to be laid out parallel with the terraces, the same number of rows should be run parallel with each terrace as indicated by the rows marked "L" in figure 18. Owing to the variation in distance between terraces it then will be necessary to fill in with short rows, generally known as "point rows." These rows, marked "S" in figure 18, are run in pairs so as to facilitate the work of cultivation.

RECLAMATION OF GULLIED LANDS.

The best results accomplished in the reclamation of badly gullied and eroded lands were found on the State agricultural experiment farm near Holly Springs, Miss. Plate IX, fig. 1, shows an extreme type of land that was completely reclaimed and made to produce crops. The gullies were partially filled by plowing the soil into them from along the edges, and further filled and levelled off by means of teams and scrapers. As soon as possible a sod of lespedeza or Bermuda grass was started over the levelled-off eroded areas. Most of the land was terraced with broad-base graded-ridge terraces, and terraces, or dams, were constructed across gullies that were too large and deep to be economically reclaimed by filling in. Ponds formed above these dams (see Pl. IX, fig. 2) which served to catch all soil carried into them from above.

Gullying can be effectively checked also by planting trees in the depressions. The native pine and black locust are recommended. Filling in gullies with straw and brush also checks erosion. In one instance a gully was practically reclaimed by dynamiting the bottom to loosen the soil and then stretching wire netting across the gulley below to catch soil particles and vegetation. The use of large pipe through a dam, with a drop drain above, is also a method which can be used effectively.

SUMMARY.

To soil erosion may be attributed the existence of much of the "worn-out" hill lands of the United States. Erosion can be controlled most effectively by the use of terraces. Although terracing is now quite widely practiced in the Piedmont region of the South, in only a few sections are efficient results being obtained. Since the comparatively few well-designed and constructed terrace systems are uniformly successful in preventing soil wash, it follows that the many failures must be ascribed to unsuitable design, faulty construction, or lack of proper maintenance.

The terraces in use in this country are of two general classes, the bench terrace and the ridge terrace, each having variations which are adapted to particular conditions of topography and soil.

The true horizontal-bench terrace is not used widely in the United States, while the sloping-bench terrace is quite common. The disadvantages of the bench terrace are that it can not be crossed by modern farm machinery; the banks can not be cultivated, while each bench must be cultivated as a separate field; weeds and objectionable grasses which grow on the banks tend to sow the entire field. It is best adapted to slopes too steep to permit the use of any form of cultivated terrace, but it can not be recommended for use on slopes exceeding 20 per cent.

The narrow-base level-ridge terrace is used extensively in the Piedmont section of the South. It is cheap to construct and easy to maintain. However, attempts to cultivate this type of terrace have not been successful generally; consequently, as in the case of the bench terrace, considerable land is lost to cultivation, and the growth of weeds and grasses on the embankments tends to seed the entire field as well as sap the strength of the adjacent soil. Outside of these objections, the narrow-base level-ridge terrace, where heavily sodded, renders satisfactory service on pervious soils and slopes not greater than 8 per cent.

The broad-base level-ridge terrace has been developed from attempts to render cultivable the narrow-base form. It has all the advantages of the latter terrace with the added one that no land is lost to cultivation. By the use of this terrace little or no soil is removed from the field. It is best adapted to use on open, pervious soils on slopes not exceeding 15 per cent, but under proper conditions of design, construction, and maintenance can be used on any soil and on slopes somewhat greater than 15 per cent.

As in the case of the level-ridge terrace, the first graded-ridge terraces were small with narrow bases, and they are subject to the same objections that apply to the narrow-base level-ridge type. Moreover, the velocity of flow of the water, due to the grade of the terrace, tends to erode the upper side of the embankment to an extent which a narrow-base terrace can not withstand.

The broad-base graded-ridge terrace (the Mangum terrace) has been adopted in many parts of the country. This terrace, properly constructed, not only can be cultivated but it can be crossed at any angle with large farm machinery. Its broad base and flat embankment slopes render it less liable to damage by the flowing water than is the case with the narrow-base type. The grade may be either uniform or variable, but both practice and theory indicate the variable-graded terrace to be superior to the uniform-graded type.

The graded terrace is adapted particularly for use on impervious and worn-out soils, and on shallow open soils with an impervious foundation—in short, soils that will not absorb much water and that necessitate the removal of most of it over the surface.

By the selection and proper construction of suitable types of terraces erosion can be controlled on slopes up to 20 per cent, or even more. Instances were found where erosion was controlled by the use of terraces on land which had a slope of 30 per cent. However, slopes steeper than 20 per cent usually can be devoted more profitably to grasses or timber than to cultivated crops. Of all types of terraces, the use of the broad-base level-ridge terrace is recommended wherever conditions will permit. This type, supplemented with efficient tile drains, offers the most ideal method of preventing soil erosion on any type of soil.

The success of a terrace system depends largely upon its proper laying off. A good leveling instrument in the hands of a competent and experienced levelman is the best insurance against failure.

Construction always should begin with the highest terrace in the field, and each terrace should be completed before starting the next lower one. The late fall and early winter is the best time to build terraces.

A terrace is susceptible to failure until it has become thoroughly settled. To facilitate settling it is best not to cultivate a terrace the first year, but to sow it to a cover crop. The best results are obtained where crop rows are run parallel with the terraces.

The instructions given herein for the selection and design of terrace systems are based upon the results of surveys, observation, and a study of terraced fields in the best-terraced sections in this country and it is believed that if they are followed carefully a great increase in the efficiency of terrace systems will result and that much better opportunity will be afforded to observe the results with a view to further improving the practice of terracing. At the same time a close study of local conditions—particularly of soil—should be made which no doubt will afford more definite information for improving further the design of a terrace system adapted to a particular locality.

Since the primary purpose of terracing is to hold the soil of the farm in place and thereby both maintain its fertility and render possible an increase of fertility by proper farming methods, all of the benefits, such as greater yields and land values, which result from the preservation and increased fertility of the soil may be attributed directly to the practice of terracing. In short, the terracing of farm lands saves the soils the most substantial and valuable asset of the country.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 513

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

Washington, D. C. ▼ March 10, 1917

FUMIGATION OF ORNAMENTAL GREENHOUSE PLANTS WITH HYDROCYANIC-ACID GAS.

By E. R. Sasscer, *Collaborator*, and A. D. Borden, *Scientific Assistant*.

CONTENTS.

INTRODUCTION.

Hydrocyanic-acid gas, if intelligently employed, is one of the cheapest and most efficient methods of controlling thrips, aphids, white flies, and various scale insects on plants grown under glass. That this method of control has not been generally adopted is no doubt owing to the deadly poisonous nature of the gas if inhaled, its disastrous effect on tender plants if improperly used, and the pre-

NOTE.—Hydrocyanic-acid gas was first used against greenhouse pests in 1895 by Messrs. A. F. Woods and P. H. Dorsett (see Circular No. 37, Bureau of Entomology, U. S. Department of Agriculture) in an effort to destroy insects on diseased plants under observation. Subsequently others have employed the gas in greenhouse fumigation, but with varying success, largely because of inexperience and improper methods of procedure. In the earlier experiments in greenhouses conducted by the Bureau of Entomology the senior author was assisted by Mr. H. L. Sanford, of the Federal Horticultural Board, and by Messrs. Eugene May, W. R. Lucas, and Charles Keller, of the Bureau of Plant Industry. The spelling of the botanical names used in this publication has been verified by Messrs. P. L. Ricker and H. C. Skeels.

CAUTION.—*Hydrocyanic-acid gas is colorless and is one of the most deadly poisonous gases known. It has an odor much like that of peach pits. In case of accidental inhalation of the gas, the person affected should be kept in the open air and required to walk to increase respiration.*

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vailing impression that fumigation is a cumbersome procedure requiring considerable skill on the part of the operator. While it is true that much damage to the plants and injury to the operator may result from the *careless* use of hydrocyanic-acid gas, it is an established fact that this fumigant in competent hands is a safe, practical, and economical means of controlling virtually all insect pests found in greenhouses.

EQUIPMENT NECESSARY FOR FUMIGATION.

GENERATORS.

One-half gallon or one-gallon glazed earthenware jars serve as satisfactory generators, although it is preferable that the bottoms of the jars be rounded inside, so that the cyanid will be covered with the acid and water, even with small doses, thus insuring the maximum generation of the gas. The number of generators required is largely influenced by the size of the house or houses to be fumigated, and to avoid unnecessary delay in case of breakage several extra crocks should be available.

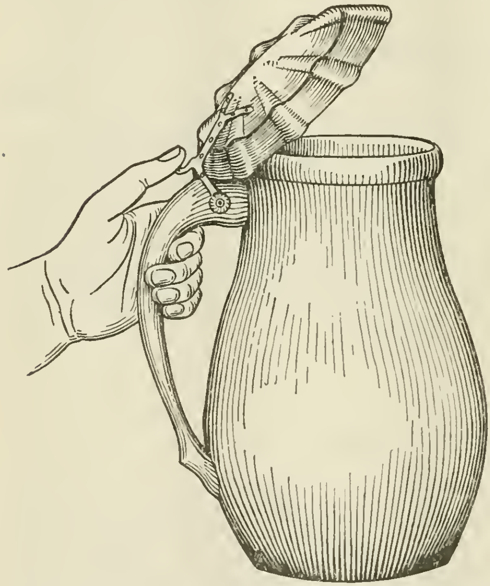

FIG. 1.—A cover device attached to a fumigation generator. Corrugations in cover allow gas to escape. (Woglum.)

To insure uniform distribution of the gas it is advisable to employ generators with covers, such as that illustrated in figure 1. This cover, which was designed by Mr. R. S. Woglum,[1] is made of copper stamped in a concave form with corrugations to permit the escape of the gas. It is attached to the generator by hinges and held in place by a bolt which extends through the handle and can be raised by a slight pressure of the thumb as shown in the figure. If it is not possible to secure crocks of this description, those with straight sides which are not constricted inside at the bottom can be used with good results, although to insure complete generation such a crock should be tilted slightly in order that the cyanid may be covered. Crocks

[1] Bul. 79, Bur. Ent., U. S. Dept. Agr., p. 58, fig. 21, 1909. Bul. 90, Part I, Bur. Ent., U. S. Dept. Agr., p. 75, fig. 12, 1911.

with straight sides are frequently sold with glazed earthenware tops. These tops or covers increase the cost of the generators and, furthermore, are useless for fumigation purposes. Therefore, when generators are ordered it should be indicated that tops are not desired. With this type of generator a cover may be improvised by using a piece of corrugated galvanized iron roofing or a board with cleats on the underside, to allow the free exit of gas.

MISCELLANEOUS REQUIREMENTS.

Correct scales or balances, reading in tenths of an ounce, are convenient for accurate work. An 8-ounce graduate is desirable for measuring the acid and water. To avoid splashing of the acid it should not be poured from a carboy or bottle into the graduate but should be transferred to a porcelain pitcher, from which it may be poured with safety. It is well to have on hand a supply of small bags or tissue paper in which to place the cyanid.

PREPARATION OF HOUSE FOR FUMIGATION.

As a preliminary to fumigating the house it is essential that the exposed glass surface be examined carefully and all broken glass replaced. All cracks should be thoroughly closed. The ventilators,

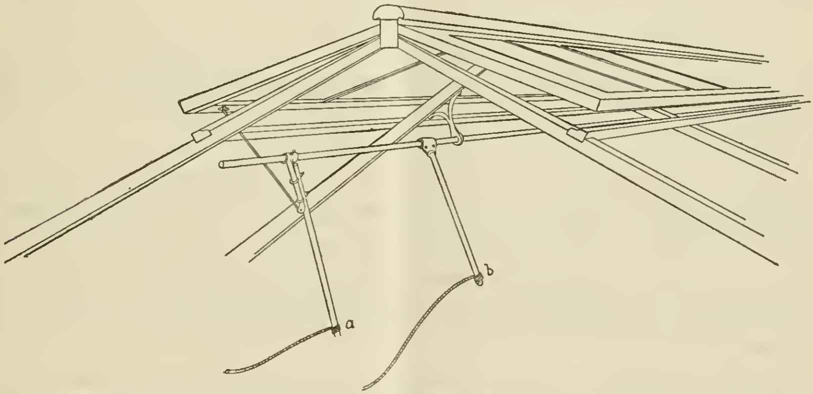

Fig. 2.—Methods of attaching rod and cord (*a*, *b*) to ventilator shaft of greenhouse so that the ventilators can be opened from the outside after fumigation. (Original.)

both side and top, where possible, should be so arranged that they can be opened on the outside of the house upon the completion of the exposure. This can be accomplished by disconnecting the "machine," or gear, of the top ventilators and attaching to the central ventilator shaft (see fig. 2) an arm (*a* or *b*) which can be controlled by a cord or wire which extends through the side of the house. The gears on the side ventilators may be disconnected so that the sash may be opened from the outside. If only one ventilator can be opened it is preferable that it be the one on the roof of the house.

METHOD OF COMPUTING THE CUBICAL CONTENTS OF EVEN AND THREE-QUARTER SPAN GREENHOUSES.

It is essential in every instance that the cubical contents of the house to be fumigated be determined accurately, and the following is a simple method of arriving at these figures: To facilitate matters a diagram indicating the necessary dimensions of the house should be made. (See figs. 3 and 4.)

To secure the cubical contents of the even-span house (fig. 4), compute the number of square feet in the rectangle *a* and in the right-angle triangles *b* and *c* and multiply the sum of the three by the length of the house. For example, A=5×20=100 square feet; B=5×10÷2=25 square feet[1]; and C=5×10÷2=25 square feet. A+B+C=150 square feet. 150 square feet × 100 feet (length of house)=15,000 cubic feet, cubic contents of the house.

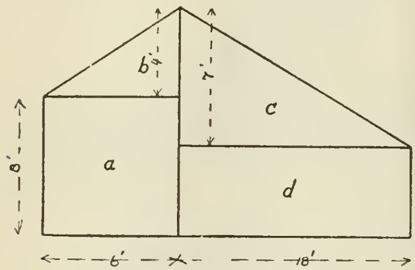

FIG. 3.—Diagram showing method of computing cubical contents of three-quarter-span greenhouse. (Original.)

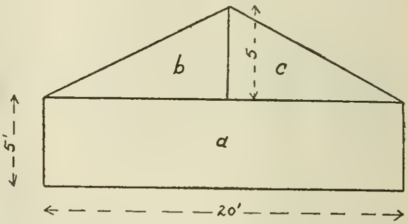

FIG. 4.—Diagram showing method of computing cubical contents of even-span greenhouse. (Original.)

To secure the cubical contents of the three-quarter span house (fig. 3) multiply the sum of the rectangles *a* and *d* and right-angle triangles *b* and *c* by the length. For example $a=6\times8=48$ square feet; $d=18\times5=90$ square feet; $b=6\times4\div2=12$ square feet; and $c=18\times7\div2=63$ square feet. $a+d+b+c=213$ square feet. 213 square feet × 100 feet (length of house)=21,300 cubic feet, cubic contents of house.

In estimating the cubic contents of a greenhouse it is not necessary to make allowances for the space occupied by the benches, pots, etc.

TIME FOR FUMIGATION.

Fumigation should be conducted not earlier than one hour after sunset and should not be attempted when the wind is high. It is undesirable to fumigate during extremely cold nights, when the thermometer is registering near zero, owing to the necessity of ven-

[1] To calculate the area of a right-angle triangle, multiply the base by the perpendicular and divide the product by two.

tilating the houses upon the completion of an exposure. It is inadvisable to fumigate on hot, humid nights, when the temperature in the house can not be lowered readily to the desired limit. The best temperature for fumigation is between 55° and 68° F.

The interval between fumigations naturally should be governed by the reappearance of the insect under control. With small dosages, which are imperative when fumigating a house containing an assortment of plants, it is possible to kill only the larvæ of scale insects, the adults and first larval stages of the greenhouse white fly, the adults of the Florida fern caterpillar, greenhouse leaf-tyer, and loopers, and a certain percentage of aphids. The eggs and pupæ of most greenhouse insects offer considerable resistance to hydrocyanic-acid gas, and furthermore the overlapping of broods necessitates several fumigations at short intervals. It has been proved repeatedly that three or four fumigations at short intervals will give practical control.

CHEMICALS REQUIRED FOR FUMIGATION.

The chemicals required in fumigating with hydrocyanic-acid gas are sodium cyanid ($NaCN$) or potassium cyanid (KCN), sulphuric acid (H_2SO_4), and water (H_2O). Potassium cyanid has been superseded recently by sodium cyanid in the generation of this gas, and the former is rarely used nowadays in fumigation. Sodium cyanid should be practically free from chlorin and contain not less than 51 per cent of cyanogen. It may be purchased either in lumps or in the shape of an egg, each "egg" weighing approximately 1 ounce. The latter is easily handled and the necessity of weighing each charge is obviated, providing, of course, the dosage is in ounces. For example, if the house requires 10 ounces of cyanid, 10 "eggs" are used. However, in small dosages, where the cyanid is measured in grams, it is necessary to use small lumps or break up the "eggs."

Cyanid is one of the most poisonous substances known and should be stored in air-tight cans, plainly labeled, and kept out of reach of those unacquainted with its poisonous nature.

Commercial sulphuric acid (about 1.84 sp. gr. or 66° Baumé) which is approximately 93 per cent pure is commonly used and gives very satisfactory results. The acid should be kept in a glass receptacle, properly labeled, and tightly corked with a glass stopper.

DETERMINING THE AMOUNT OF CYANID TO BE USED.

Satisfactory results are obtained only where it is possible to overcome the resisting power of the insects without overcoming the resisting power of the plant. Tender succulent plants, such as roses, geraniums, coleus, sweet peas, Wandering Jew, etc., are more susceptible to injury by hydrocyanic-acid gas than are certain hardy ornamentals, and this fact should be considered where an assortment of plants is to be fumigated. In case there is any doubt as to the amount of gas a plant will stand without injury, it is preferable that the initial dosage be not over one-fourth ounce of sodium cyanid per 1,000 cubic feet and increased with subsequent fumigations until the fatal point of the pest to be controlled is reached, it being borne in mind that in some instances it is not possible to effect an absolute control of all stages of some insects with one fumigation without injury to foliage or growing parts of certain plants. For example, the greenhouse white fly has been eradicated with three successive fumigations at intervals of 7 to 9 days, using one-half ounce of sodium cyanid (NaCN) per 1,000 cubic feet, in houses containing such susceptible plants as coleus, ageratum, heliotrope, fuchsia, etc., with no injury to the foliage. Moreover, such resistant pests as scale insects can be eliminated entirely by killing the immature stages with a small dosage repeated at frequent intervals.

Under favorable conditions houses which do not contain roses, rose geraniums, asparagus ferns, lemon verbena, snapdragon, Wandering Jew, or sweet peas can be fumigated with safety with an initial dosage of one-half ounce of sodium cyanid (NaCN) per 1,000 cubic feet.

To determine the total amount of cyanid to be used, ascertain from the tables on pages 12–18 the plants in your greenhouse which are most easily injured by the gas fumes and note the amount of cyanid which was used per 1,000 cubic feet with little or no injury to the plants. Then multiply the number of thousand cubic feet contained in the house by the amount of cyanid to be used per 1,000 cubic feet. For example, if one-half ounce of cyanid is to be used per 1,000 cubic feet, and the house contains 15,000 cubic feet, the total amount of cyanid necessary would be 7½ ounces.

In case there is any doubt as to the amount of gas the plant can stand without injury, the initial dosage, as previously stated, should not exceed one-fourth ounce per 1,000 cubic feet.

CHEMICAL FORMULA TO BE EMPLOYED.

The chemicals[1] should be mixed in the following proportions: For each ounce of sodium cyanid use 1½ fluid ounces of sulphuric acid and 2 fluid ounces of water.

[1] If potassium cyanid is used in place of sodium cyanid, the formula should be as follows: For each ounce of 98 to 99 per cent potassium cyanid containing 38.4 per cent cyanogen use 1 ounce of sulphuric acid and 3 ounces of water. The yield from 1 ounce of high-grade sodium cyanid is equivalent to the yield from 1⅓ ounces of high-grade potassium cyanid.

MIXING THE CHEMICALS.

After the generators have been distributed throughout the greenhouse, and before the chemicals have been mixed, the cyanid should be weighed accurately and the proper amount for each generator placed in a paper bag near the generator. The chemicals should be mixed invariably in the following manner: First, measure and place in each generator the amount of water required; second, measure and place in each generator the amount of sulphuric acid required; third, drop the cyanid into the diluted warm acid in each generator, close the covers, immediately leave the house, and post a danger sign on the closed door. The cyanid should be dropped gently, not thrown, into the generators, and the operator should begin at the generator farthest from the door and work toward the door. In case there are two rows of generators the cyanid should be dropped simultaneously by two operators. As little time as possible should elapse between the addition of the acid and the addition of the cyanid, as the heat which is liberated by the mixing of the acid and water assists in the generation of the gas.

The residue left in the generators after fumigation should be buried or poured into a sink and the generator washed before being stored for future operations.

NUMBER OF GENERATORS TO BE EMPLOYED.

The number of generators will depend largely upon the size of the house, and they should be so arranged that the gas will be uniformly distributed throughout the inclosure. To secure this advantage, it is advisable that a number of generators be used rather than one large generator. Generators should be spaced from 20 to 25 feet apart, and in case of a light wind a few extra generators should be placed on the windward side of the house. An ounce to each jar is as small a dose as is practicable, unless the generators are well rounded inside at the base or well tilted.

EXPOSURES.

Short exposures with a greater strength of gas have been found more satisfactory than a weaker strength of gas overnight. In fact, better results will be gained if the exposures do not exceed one to two hours. An exposure of one hour is satisfactory in most instances. Short exposures also have the additional advantage of permitting the house to become thoroughly aerated previous to the rising of the sun.

VENTILATION AFTER FUMIGATION.

If there is a light wind, a ventilation of 10 to 15 minutes, using side and top ventilation, will be sufficient and will not lower the house temperature to a dangerous point unless it is close to zero weather outside. If it is a still evening and the outside temperature is not below 32° F., a 20 to 30 minute ventilation is satisfactory.

In case it is necessary to enter the house shortly after ventilation to determine the temperature, the person entering should not remain any longer than is necessary.

EFFECTS OF WEATHER CONDITIONS ON FUMIGATION.

TEMPERATURE.

Much experimentation has proved that excessive heat and cold will affect the results of fumigation. In most instances it is not advisable to fumigate if the temperature in the frame exceeds 70° F., or if the temperature is less than 55° F. It is possible that a variation of five degrees from the latter temperature will not result in serious injury to the plants, providing, of course, that the plants are not affected by such a low temperature.

LIGHT.

Light unquestionably affects fumigation. It has been known for a long time that it is very undesirable to fumigate when the sun is high. Furthermore, recent experiments have demonstrated that some injury may result to plants which have been subjected to fumes if, on the following day, the sun is very bright.

MOISTURE.

The question of moisture has received considerable attention from various fumigators, and it appears to be the consensus of opinion that excessive moisture in the presence of the gas does not increase the injury to plants and plant products under fumigation. A large number of plants have been fumigated in boxes immediately after syringing, when the leaves were covered with a film of water, with apparently no injury to the plants, and the insects on the plants were successfully controlled, which corroborates the experience of Morrill,[1] Quaintance,[2] and Woglum.[3]

Hydrocyanic-acid gas is readily soluble in water, and as a result the presence of excessive moisture in greenhouses decreases the effectiveness of the gas and consequently lessens the possibility of injury to the plants by burning. Fumigation experiments have been

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[1] Bul. 76, Bur. Ent., U. S. Dept. Agr., p. 12, 1908.
[2] Bul. 84, Bur. Ent., U. S. Dept. Agr., p. 24, 31, 1909.
[3] Bul. 90, Bur. Ent., U. S. Dept. Agr., p. 68, 1912.

conducted where the plants, beds, and walks were thoroughly soaked with water, and the injury which would be expected under normal conditions to such plants as cosmos, rose geraniums, roses, heliotropes, and *Asparagus plumosus* did not appear, nor were such insects as aphids and thrips appreciably affected. It is obvious, therefore, that in order to increase the effectiveness of the fumigation the plants should be syringed not less than four or five hours prior to the liberation of the gas, to avoid undue absorption of the gas by the water on the benches and walks.

The difference in the results noted above may be accounted for by the fact that in the case of box fumigation only the foliage was covered with a film of water, whereas in the case of the greenhouse experiments not only the foliage of the plants was covered with a film of water but the entire soil surface of the house was soaked, and the water undoubtedly absorbed much of the available gas, reducing the toxic effect of the gas on the plants and insects.

HUMIDITY.

Recent tests have demonstrated that a relatively high humidity (98 to 100), with temperature varying from 70° to 75° F., greatly increases the amount of injury to the foliage of the plants, whereas plants in the presence of a relatively high humidity (98 to 100), with a temperature of 60° to 65° F., do not exhibit injury in excess of that which would appear if the plants were fumigated with an excessive dosage under normal atmospheric conditions. It is apparent, therefore, that a relatively high humidity alone is not responsible for injury unless accompanied by temperatures exceeding 70° F.

ADVISABILITY OF A FUMIGATION BOX.

A fumigation box is desirable for two reasons, namely, for testing the amount of gas plants can stand without injury, and for ridding a limited number of potted plants of insects, and thus avoiding costly and laborious hand scrubbing of such plants. The size of the box will depend on the use to which it is to be put. A box with a capacity of 200 cubic feet can be used advantageously for nursery stock, palms, etc.

Plants to be fumigated in a box in the daytime should remain in the box with the door closed at least one hour before the gas is generated and should be shaded from the bright sunlight for at least two hours after the completion of the exposure.

HOW INSECTS ARE DISSEMINATED FROM HOUSE TO HOUSE.

Doubtless many houses become infested with insects through the agency of plants commonly referred to as "boarders." The practice of turning over home-grown plants to a florist to care for during the absence of the owner on a vacation is prevalent over the entire country, and often results in establishing pests not hitherto known to occur on the florist's premises. If the trade requires such a practice, plants of this character should be cleaned thoroughly of insect pests before being placed with the regular stock of the greenhouse.

Insect infestations in greenhouses have been traced to the following sources: Infested plants brought in from cold frames or propagation beds which have not received proper attention; cuttings, plants, and buds received from other establishments; and imported foreign or domestic stock. Adults of the greenhouse white fly, grasshoppers, beetles, aphids, etc., may enter through open ventilators from other houses or gardens; cutworms, wireworms, white grubs, etc., may be brought into the house with the soil; and roaches, ants, sowbugs, millipeds, etc., are sometimes brought in with packages, or they may crawl into the house through small openings.

COST OF HYDROCYANIC-ACID GAS FUMIGATION.

The economy in the use of hydrocyanic-acid gas as a means of controlling aphids, white flies, thrips, and the common greenhouse scale insects is apparent from the following figures, which are based on current prices:

Aphids can be controlled with a single fumigation at the rate of one-fourth ounce per 1,000 cubic feet at a cost of approximately ½ cent per 1,000 cubic feet. Tobacco fumigation with standard tobacco paper costs from 1½ to 3 cents per 1,000 cubic feet, and to secure a satisfactory control the operation must be repeated several times. Standard nicotine soap solution costs from 1 to 3 cents per gallon, and 4 gallons are required to cover plants which would occupy 1,000 cubic feet of space.

The greenhouse white fly can be controlled in three successive fumigations at the rate of one-half ounce of sodium cyanid per 1,000 cubic feet, with a total cost of 3 cents per 1,000 cubic feet for a complete control. Standard insecticides cost about 6 cents per 1,000 cubic feet for a single application, and fully four applications are required for a satisfactory control.

Thrips can be controlled on such plants as azaleas, lilies, and ferns with a single fumigation at the rate of one-half ounce of sodium cyanid per 1,000 cubic feet at a cost of 1 cent per 1,000 cubic feet. A single application of nicotine soap solution costs fully five times as much as the gas treatment and still gives only a partial control.

The common scale insects of greenhouses (excepting mealy bugs) can be controlled by fumigating the infested plants at the rate of three-fourths ounce of sodium cyanid per 1,000 cubic feet at a cost of 1½ cents per 1,000 cubic feet. The standard proprietary insecticides commonly recommended for scale insects cost approximately 4 cents per gallon with an average cost of 16 cents per 1,000 cubic feet for each treatment. A 5 per cent homemade kerosene emulsion costs approximately one-half cent more per 1,000 cubic feet than does the gassing method, and gives very indifferent results.

The foregoing figures do not take into consideration the cost of labor. However, the time required for fumigation will not exceed the time required for the mixing and application of the sprays.

PRECAUTIONS.

Do not *guess* the amount of chemicals to be employed or the cubic contents of the house.

Do not fumigate plants in a greenhouse in daylight. (For box fumigation in daytime, see page 9.)

Do not fumigate when the temperature in the house is below 50° or above 70° F.

Do not leave the chemicals within reach of those unacquainted with their poisonous nature. Always have them properly labeled.

Do not handle the chemicals any more than is absolutely necessary, and always wash the hands thoroughly after doing so. It is well to have a pair of old gloves for this, and to use them for no other purpose.

Do not allow the acid to splash or drop on the clothing or skin.

Do not stay in the house any longer than is necessary to place the cyanid in the jars, and *never* enter a house charged with gas until it has been thoroughly aired.

Do not fail to post danger signs at all entrances before setting off the charge, and to see that the house is tightly closed.

Do not attempt to fumigate without adjusting the ventilators so that they may be operated from the outside.

Do not attempt to fumigate a large house alone.

Do not fumigate a frame adjoining a dwelling without notifying the occupants before fumigation and allowing them time to leave. Houses contiguous to fumigated frames should be aired thoroughly before the occupants are allowed to reenter.

Do not pour the water on the acid; pour the acid on the water.

Do not become negligent in any of the precautions; to do so may cause serious results.

PLANTS AND INSECTS FUMIGATED IN GREENHOUSES.

Table I is offered as a guide to those desiring to employ hydrocyanic-acid gas for controlling greenhouse pests. Space will not permit the inclusion of all plants which have been fumigated by the writers, but the table includes many ornamentals and a few tropical and subtropical plants commonly grown in greenhouses.

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses.*

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Abutilon sp	½		1	70	Greenhouse white fly.	No burning	All stages except egg and late pupæ killed.
Do	½		1	58	do	do	Do.
Do	¾		1	68	do	do	Do.
Do	¾		1	56	do	do	Do.
Abutilon vitifolia	½		1	64	do	do	Do.
Do	½		1	77	do	do	Do.
Acalypha sp	½		1	60		do	
Do	½		1	64		do	
Do	¾		1	60		do	
Achania sp		½	¾	52		do	
Do		¾	1			do	
Achyranthes sp	½		1	58		do	
Do	½		1	64		do	
Do	¾		1	55		do	
Do	¾		1	60		do	
Actinidia polygama		1 3/7	1	73		Slight burning	
Adenocalymma cosmosum		5	¾	66		No burning	
Agave americana	¾		1	68		do	
Agave sp		5/7	½			do	
Ageratum sp	½		1	64		do	
Do	½		1	58	Greenhouse white fly.	do	All stages except eggs and late pupæ killed.
Do	½		1	64	do	do	
Do	¾		1	56	do	do	
Air plant	½		1	70	Aphids	do	100 per cent killed.
Do	¾		1	68	do	do	Do.
Albizzia sp		1 3/7	1	73		Slight burning	
Aleurites sp		1 3/7	1	73		do	
Alpinia nutans	½		1	62		No burning	
Do	½		1	74		do	
Althaea sp		1 4/5	½		Aphids	do	Do.
Amaranthus sp	¾		1	55		do	
Amaryllis sp	½		1	60		do	
Do	½		1	70		do	
Do	¾		1	68		do	
Annona cherimola		5/7	½			do	
Annona sp		1 3/7	1	73		Slight burning	
Antidesma bunius		1 3/7	1	73		do	
Anthericum sp	½		1	60	Long scale	No burning	80 per cent killed.
Do	½		1	64		do	
Do	¾		1	60	Long scale	do	100 per cent killed.
Anthurium sp		5/7	½			do	
Aralia guilfoylei	½		1	66		do	
Ardissia sp	½		1	62		do	
Do	½		1	74		do	
Araucaria excelsa	½		1	66		do	
Do	½		1	77		do	
Aristolochia sp		5	¾	66		do	
Artemisia sp	1 3/7		1	73		Slight burning	
Artillery plant	½		1	70		No burning	
Asparagus plumosus	½		1	66		Tips burned	
Do	½		1	70		do	
Do	½		1	60		do	
Do	¾		1	68		Severe burning.	
Asparagus sprengeri	½		1	60		Tender tips burned.	
Do	½		1	70		No burning	
Do	¾		1	68		Tender tips burned.	
Do	¾		1	55		do	
Aspidistra sp	½		1	62		No burning	
Do	½		1	74		do	
Aster	½		1	62		do	
"Atamasco"	½		1	64		do	
Do	½		1	76		do	
Atropa sp	½		1	64		do	
Do	½		1	76		do	

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Aucuba japonica	½		1	66		No burning	
Do	½		1	77		do	
Do	¾		1	68		do	
Avocado, see *Persea*.							
Azalea indica		5	¾	66		do	
Azalea sp	½		1	60	Thrips	do	95 per cent killed.
Do					Azalea lace-wing.	do	100 per cent killed.
Do	¾		1	60	Azalea Eriococcus.	do	50 per cent killed.
Do	¾		1	55		do	
Do		5	¾	52		do	
Do		7½	1			Slight burning	
Bamboo		1 3/7	1	73		Slight burning.	
Banana	½		1	60		No burning	
Do	¾		1	55		do	
Basanacantha sp		1 3/7	1	73		Severe burning.	
Begonia argenteoguttata	½		1	60	Orthezia	No burning	70 per cent killed.
Do	½		1	64		do	
Do	¾		1	60		do	
Begonia diadema	½		1	60		do	
Do	½		1	58		do	
Do	¾		1	56		do	
Begonia erfordii		5	¾	66		do	
Begonia manicata	½		1	60		do	
Do	½		1	58		do	
Do	¾		1	56		do	
Begonia metallica	½		1	66		do	
Do	½		1	77		do	
Begonia ricinifolia	½		1	60		do	
Do	½		1	58		do	
Do	¾		1	56		do	
Begonia saundersoni	½		1	58		do	
Do	½		1	64		do	
Do	¾		1	56		do	
Do	¾		1	60		do	
Begonia (Leopard)	½		1	66		do	
Do	½		1	77		do	
Begonia (Lorraine)	½		1	62		do	
Do	½		1	74		do	
Begonia (Rex)	½		1	66		do	
Do	½		1	77		do	
Berberis rehderiana	½		1	62		do	
Do	½		1	74		do	
Berberis thunbergii		1 4/5	½		Aphids	Slight burning.	100 per cent killed.
Berberis vulgaris		1 4/5	½		do	do	Do.
Berberis sp		1 3/7	1	73		do	
Belladonna	½		1	62		No burning	
Do	½		1	74		do	
Bougainvillea	½		1	58		do	
Do	½		1	60		do	
Do	¾		1	56		do	
Bradburya		1 3/7	1	73		Slight burning.	
Bromelia sp		1 3/7	1	73		Severe burning.	
Bunchosia sp		1 3/7	1	73		Slight burning.	
Buxus sp. (boxwood)		5	¾	52		No burning	
Do		7½	1			do	
Cactus	½		1	70		do	
Do	¾		1	68		do	
Calla lily	½		1	64		do	
Do	½		1	76		do	
Do		5	¾	66		do	
Caladium sp	¾		1	55		do	
Do		5/7				do	
Camellia japonica		5	¾	52		do	
Camellia sp	¾		1	55		do	
Do		7½	1			do	

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Camoensia sp	......	$1\frac{3}{7}$	1	73	....	Slight burning.	
Canaga odorata	$\frac{1}{2}$	......	1	66	....	No burning	
Do	$\frac{1}{2}$	......	1	77	....	....do	
Canna	$\frac{1}{2}$	......	1	64	....	....do	
Do	$\frac{1}{2}$	......	1	77	....	....do	
Carica papaya	......	$1\frac{3}{7}$	1	73	....	Slight burning	
Carissa carandas	......	$\frac{5}{7}$	$\frac{1}{2}$	....	....	No burning	
Do	......	$1\frac{3}{7}$	1	73	....	Slight burning.	
Carnation	$\frac{1}{2}$	......	....	62	....	No burning	
Do	$\frac{1}{2}$	......	1	76	....	....do	
Do	$\frac{3}{4}$	......	1	55	....	....do	
Cassia beareana	......	$1\frac{3}{7}$	1	73	....	Slight burning.	
Cassia fistula	......	$1\frac{3}{7}$	1	73	....	....do	
Catha edulis	$\frac{1}{2}$	......	1	66	....	....do	
Do	$\frac{1}{2}$	......	1	77	....	....do	
Ceiba pentandra	......	$1\frac{3}{7}$	1	73	....	....do	
Centaurea	$\frac{1}{2}$	......	1	60	Onion thrips	....do	95 per cent killed.
Cereus (night-blooming)	$\frac{1}{2}$	......	1	64	....	No burning	
Do	......	$\frac{5}{7}$	$\frac{1}{2}$	....	....	....do	
Ceropegia thorncroftii	......	$1\frac{3}{7}$	1	73	....	Severe burning.	
Chrysanthemum	$\frac{1}{2}$	......	1	62	....	....do	
Do	$\frac{1}{2}$	......	1	76	Aphids	....do	100 per cent killed.
Do	$\frac{3}{4}$	......	1	68	....	....do	
Do	......	5	$\frac{3}{4}$	66	....	....do	
Cigar plant	$\frac{1}{2}$	......	1	70	Aphids	....do	Do.
Do	$\frac{3}{4}$	......	1	68	....	....do	
Cineraria	$\frac{3}{4}$	......	1	60	....	Old foliage burned.	
Cinnamomum camphora	$\frac{1}{2}$	......	1	66	....	No burning	
Do	$\frac{1}{2}$	......	1	77	....	....do	
Do	$\frac{3}{4}$	......	1	68	....	....do	
Citrus aurantium	$\frac{1}{2}$	......	1	60	Long scale	....do	80 per cent killed.
Do	$\frac{3}{4}$	......	1	55	....	....do	
Citrus plumbago	......	5	$\frac{3}{4}$	52	....	....do	
Citrus sp	$\frac{1}{2}$	......	1	64	....	....do	
Do	......	$1\frac{3}{7}$	$\frac{1}{2}$	....	Florida red scale.	....do	90 per cent killed.
Do	......	$7\frac{1}{2}$	1	....	....	....do	
Do	......	10	$1\frac{1}{3}$	....	....	Tender foliage burned.	
Clianthus dampieri	$\frac{1}{2}$	......	1	62	....	No burning	
Do	$\frac{1}{2}$	......	1	74	....	....do	
Clerodendron	......	5	$\frac{3}{4}$	66	....	....do	
Cockscomb	$\frac{1}{2}$	......	1	64	....	....do	
Coleus (Black Prince)	$\frac{1}{2}$	......	1	60	Orthezia	....do	75 per cent killed.
Do	$\frac{3}{4}$	......	1	66	....do	Old foliage burned.	80 per cent killed.
Coleus (Firebrand)	$\frac{1}{2}$	......	1	60	....do	No burning	75 per cent killed.
Do	$\frac{3}{4}$	......	1	60	....do	....do	80 per cent killed.
Coleus (Golden bedder)	$\frac{1}{2}$	......	1	60	....do	....do	75 per cent killed.
Do	$\frac{3}{4}$	......	1	60	....do	Old foliage burned.	80 per cent killed.
Coleus (Golden Queen)	$\frac{1}{2}$	......	1	60	....do	No burning	75 per cent killed.
Do	$\frac{3}{4}$	......	1	60	....do	....do	80 per cent killed.
Coleus (Mrs. Hayes)	$\frac{1}{2}$	......	1	60	....do	....do	70 per cent killed.
Do	$\frac{3}{4}$	......	1	60	....do	....do	80 per cent killed.
Coleus (Pfeister Red)	$\frac{1}{2}$	......	1	60	....do	....do	70 per cent killed.
Do	$\frac{3}{4}$	......	1	60	....do	....do	80 per cent killed.
Coleus (Pfeister Yellow)	$\frac{1}{2}$	......	1	60	....do	....do	70 per cent killed.
Do	$\frac{3}{4}$	......	1	60	....do	....do	80 per cent killed.
Coleus (Rose Bank)	$\frac{1}{2}$	......	1	60	....do	....do	70 per cent killed.
Do	$\frac{3}{4}$	......	1	60	....do	....do	80 per cent killed.
Coleus (Shirrock Jr.)	$\frac{1}{2}$	......	1	60	....do	....do	70 per cent killed.
Do	$\frac{3}{4}$	......	1	60	....do	Old foliage burned.	80 per cent killed.
Coleus (Queen Victoria)	$\frac{1}{2}$	......	1	60	....do	No burning	70 per cent killed.
Do	$\frac{3}{4}$	......	1	60	....do	....do	80 per cent killed.

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°*F.*			
Coleus (Verschaffelti)	$\frac{1}{2}$	......	1	60	Orthezia	No burning	70 per cent killed.
Do	$\frac{3}{4}$	......	1	60	do	do	80 per cent killed.
Coleus (mixed)	$\frac{1}{2}$	......	1	64	do	do	100 per cent killed.
Coreopsis	$\frac{1}{2}$	......	1	62		do	
Cosmos	$\frac{1}{2}$	......	1	60		Tips burned	
Do	......	$1\frac{3}{7}$	1	73		Slight burning	
Cotton	$\frac{1}{2}$	......	1	66		No burning	
Do	$\frac{1}{2}$	......	1	77		do	
Do	......	$\frac{5}{7}$	$\frac{1}{2}$	....	Greenhouse white fly.	do	All stages except eggs and late pupæ killed.
Croton (mixed varieties)	$\frac{1}{2}$	......	1	58		do	
Do	$\frac{1}{2}$	......	1	77		do	
Do	$\frac{3}{4}$	......	1	56	Long scale	do	100 per cent killed.
Do	......	$1\frac{4}{5}$	$\frac{1}{2}$	....		do	
Cudrania javanensis	......	$1\frac{4}{5}$	1	73		Slight burning	
Cudrania tricuspidata	......	$1\frac{4}{5}$	1	73		do	
Cyclamen	$\frac{1}{2}$	......	1	58		No burning	
Do	$\frac{1}{2}$	......	1	74		do	
Do	$\frac{3}{4}$	......	1	68		do	
Cyphomandra sp	......	$1\frac{4}{5}$	1	73		Slight burning	
Daffodil	$\frac{3}{4}$	......	1	55		No burning	
Do	......	$1\frac{4}{5}$	1	73		Severe burning of new foliage.	
Deutzia gracilis	......	$1\frac{4}{5}$	$\frac{1}{2}$	....	Aphids	No burning	100 per cent killed.
Deutzia scabra	......	$1\frac{4}{5}$	$\frac{1}{2}$	....		do	
Digitalis	$\frac{1}{2}$	......	1	62		do	
Do	$\frac{1}{2}$	......	1	74		do	
Dioscorea pentaphylla	$\frac{1}{2}$	......	1	64		do	
Do	$\frac{1}{2}$	......	1	76		do	
Dracaena godseffiana	......	5	$\frac{3}{4}$	66		do	
Dracaena indivisa	......	5	$\frac{3}{4}$	52		do	
Do	......	$7\frac{1}{2}$	1	....		do	
Entclea palmata	......	$1\frac{3}{7}$	1	73		Slight burning	
Erica sp	$\frac{1}{2}$	......	1	64		No burning	
Do	$\frac{1}{2}$	......	....	76		do	
Epiphyllum sp	$\frac{1}{2}$	......	1	64		do	
Do	$\frac{1}{2}$	......	1	76		do	
Eupatorium sp	$\frac{1}{2}$	......	1	58		do	
Do	$\frac{3}{4}$	......	1	60		do	
Do	......	$1\frac{3}{7}$	1	73		Severe burning of young foliage.	
Ferns:[1]							
Adiantum cuneatum	$\frac{3}{4}$	......	1	60		No burning	
Adiantum croweanum	$\frac{3}{4}$	......	1	60		do	
Birds nest	$\frac{1}{2}$	......	1	70		do	
Do	$\frac{3}{4}$	......	1	68		do	
Boston	$\frac{1}{2}$	......	1	60		do	
Do	$\frac{3}{4}$	......	1	68		do	
Holly	......	5	$\frac{3}{4}$	52		do	
Do	$\frac{1}{2}$	......	1	62		do	
Do	$\frac{3}{4}$	......	1	60		do	
Lastrea sp	$\frac{1}{2}$	......	1	70		do	
Do	$\frac{3}{4}$	......	1	68		do	
Nephrolepis scottii	$\frac{3}{4}$	......	1	55		do	
Nephrolepis scholzelii	$\frac{3}{4}$	......	1	55		do	
Nephrolepis whitmanii	$\frac{1}{2}$	......	1	62		do	
Do	$\frac{3}{4}$	......	1	68		do	
Polystichum sp	$\frac{1}{2}$	......	1	70		do	
Do	$\frac{3}{4}$	......	1	60		do	
Pteris sp	$\frac{1}{2}$	......	1	60		do	
Ficus utilis	......	$1\frac{3}{7}$	1	73		Slight burning of new growth.	
Ficus sp	......	$2\frac{1}{2}$	$\frac{3}{4}$	....	Cottony scale.	No burning	All stages except eggs killed.

[1] *Asparagus plumosus* and *A. sprengeri* belong to the Lily family and are to be found under *Asparagus*.

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Ficus sp.	......	7½	1	....	Thread scale	Severe burning; all leaves knocked. Injury largely due to close proximity of generator to plant.	All stages killed.
Forgetmenot	......	7½	1	....	....	Severe burning of tender foliage.	
Forsythia viridissima	......	1⅘	½	....	Aphids	No burning	100 per cent killed.
Freesia	½	......	1	60	....	....do	
Do	¾	......	1	60	....	....do	
Fuchsia	½	......	1	60	Greenhouse white fly.	....do	All stages except eggs and late pupæ killed.
Do	¾	......	1	68	....do	....do	Do.
Do	......	5	¾	66	....	Slight burning	
Gaillardia sp.	½	......	1	62	....	No burning	
Gardenia	½	......	1	60	....	....do	
Do	¾	......	1	68	....	....do	
Do	......	5	¾	66	....	....do	
Do	......	7½	1	....	....	Slight burning	
Genista	¾	......	1	55	....	No burning	
Do	......	5	¾	66	....	Flowers burned.	
Geraniums:							
Martha Washington	½	......	1	70	Aphids	New growth burned.	60 per cent killed.[1]
Do	½	......	1	70	....do	....	100 per cent killed.[1]
Peppermint	½	......	1	70	....	No burning	
Do	¾	......	1	68	....	....do	
Bedding	½	......	1	60	Greenhouse white fly.	....do	All stages except eggs and late pupæ killed.
Do	¾	......	1	68	....do	....do	Do.
Rose	½	......	1	64	....	New growth burned.	
Gladiolus	½	......	1	62	....	No burning	
Do	¾	......	1	55	....	....do	
Heather (Scotch)	½	......	1	70	....	....do	
Do	¾	......	1	68	....	....do	
Do	......	5	¾	52	....	Slight burning	
Do	......	7½	⅔	....	....	....do	
Heliotrope	½	......	1	64	....	No burning	
Do	¾	......	1	60	....	....do	
Hibiscus sp.	½	......	1	60	....	....do	
Do	¾	......	1	55	....	....do	
Hyacinth (water)	½	......	1	64	....	....do	
Do	¾	......	1	55	....	....do	
Hydrangea (French variety).	½	......	1	64	....	....do	
Do	¾	......	1	60	....	....do	
Ilex sp. (English)	......	5	¾	52	....	....do	
Do	......	7½	1	....	....	....do	
Impatiens sultani	½	......	1	66	Aphids	....do	100 per cent killed.
Do	¾	......	1	68	....	....do	
Ipomoea sp. (morning glory).	½	......	1	64	....	....do	
Do	¾	......	1	60	....	....do	
Iris (Spanish)	½	......	1	64	....	....do	
Do	......	5	¾	66	....	Tips burned	
Lantana sp.	½	......	1	60	*Orthezia*	No burning	70 per cent killed.
Do	¾	......	1	56	....	....do	
Laurus nobilis	......	5	¾	52	Soft brown scale.	....do	Immature stages killed.
Do	......	7½	1	....	....do	....do	90 per cent killed.

[1] The difference in results noted was due to the difference in the tightness of the two houses.

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
Lilies:				°F.			
Lilium formosum	1/2		1	60	Aphids	No burning	100 per cent killed.
Do	3/4		1	60		do	
Lilium multiflorum	1/2		1	60	Aphids	do	Do.
Do	3/4		1	60		do	
Chinese	3/4		1	55		do	
Water		5	3/4	66		do	
Loquat		1 3/7	1	73		Slight burning	
Mango	1/2		1	60		No burning	
Do	3/4		1	55		do	
Do	5		1/2		Aphids	Slight burning	Do.
Marguerite	1/2		1	70	do	No burning	Do.
Do	1/2		1	60	Hemispherical scale.	do	95 per cent of immature scales killed.
Do	3/4		1	68		do	
Marigold (French)	1/2		1	60		do	
Do	3/4		1	64		do	
Mignonette	1/2		1	60		do	
Mimulus moschatus	1/2		1	70		do	
Do	3/4		1	56		do	
Moon vine	1/2		1	60		Open flowers burned.	
Do	3/4		1	60		Flowers and buds burned.	
Narcissus poeticus	3/4		1	55		No burning	
Narcissus barri	3/4		1	55		do	
Nasturtium	3/4		1	55		do	
Nigella	1/2		1	62	Aphids	do	100 per cent killed.
Do		1 4/5	1/2			do	
Oleander	1/2		1	66		do	
Do		5	1/2	76		do	
Olive		5/7	1/2			do	
Orchid:							
Cattleya trianae	1/2		1	64		do	
Oxalis (flowering)	1/2		1	58		do	
Do	3/4		1	56		do	
Palms:							
Areca lutescens	3/4		1	60		do	
Chamaerops pumila	1/2		1	66		do	
Do	1/2		1	77		do	
Cocos sp		5/7	1/2			do	
Kentia belmoriana	1/2		1	60		do	
Do	3/4		1	60		do	
Latania sp	3/4		1	60		do	
Phoenix canariensis		5	3/4	66		do	
Pandanus graminifolius	1/2		1	70		do	
Do	3/4		1	68		do	
Pandanus veitchi	1/2		1	70		do	
Do	3/4		1	68		do	
Pansy	1/2		1	62	Aphids	do	Do.
Do	3/4		1	55	do	do	Do.
Pelargonium odoratissimum		1 3/7	1	73		Slight burning	
Pelargonium sp	1/2		1	62		No burning	
Do	3/4		1	68	Aphids	do	75 per cent killed.
Pentstemon		5	3/4	52		do	
Do		7 1/2	1			Slight burning.	
Persea americana		3/4	1	55	Hemispherical scale.	No burning	100 per cent immature scales killed.
Do		1 3/7	1	73		Slight burning.	
Do		3/4	1	66	Avocado white fly.	No burning	All stages except eggs and late pupæ killed.
Petunia	1/2		1	60		do	
Poinsettia	1/2		1	62		do	
Pomegranate		6/7				do	
Poppy (Shirley)	1/2		1	60		do	

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°*F.*			
Primula chinensis	1/2	......	1	58	......	No burning	
Do	3/4	......	1	56	......	do	
Do	......	5	3/4	66	......	do	
Primula malacoides	3/4	......	1	55	......	do	
Primula obconica	1/2	......	1	58	Greenhouse white fly.	do	All stages except eggs and late pupæ killed.
Do	3/4	......	1	55	......	do	
Psidium guajava	......	5/7	1/2	....	......	do	
Do	......	1 3/7	1/2	....	Long scale	do	Immature stages killed.
Rhododendron	......	5	3/4	66	......	do	
Rhyncospermum sp	......	7 1/2	1	....	......	do	
Rosemary	1/2	......	1	64	......	do	
Do	1/2	......	1	76	......	do	
Rose	1/2	......	1	64	......	Tender growth burned.	
Do	1/2	......	1	62	Rose leafhopper.	do	100 per cent killed.
Do	......	1 3/7	1	73	......	do	
Sage, scarlet	1/2	......	1	74	......	No burning	
Do	1/2	......	1	60	......	do	
Do	3/4	......	1	60	......	do	
Schizanthus sp	1/2	......	1	60	......	do	
Do	3/4	......	1	56	......	do	
Scilla nutans	3/4	......	1	55	......	do	
Smilax	......	5	3/4	52	......	do	
Do	......	7 1/2	1	....	......	Severe burning.	
Snapdragon	1/2	......	1	60	......	Tender tips burned.	
Do	3/4	......	1	60	......	do	
Spiraea cantoniensis	......	1 4/5	1/2	....	Aphids	No burning	Do.
Spiraea latifolia	......	1 4/5	1/2	....	do	do	Do.
Spiraea thunbergii	......	1 4/5	1/2	....	do	do	Do.
Spiraea vanhouttei	......	1 4/5	1/2	....	do	do	Do.
Spiraea sp	3/4	......	1	60	......	do	
Stephanandra flexuosa	......	1 4/5	1/2	....	Aphids	do	Do.
Stephanotis floribunda	......	5	3/4	66	......	do	
Stevia sp	1/2	......	1	60	......	do	
Stocks	1/2	......	1	62	......	do	
Sweet peas	1/2	......	1	62	Aphids	Tips and blossoms burned.	Do.
Thunbergia erecta	1/2	......	1	64	......	No burning	
Do	1/2	......	1	76	......	do	
Tulip	3/4	......	1	55	......	do	
Verbena	1/2	......	1	64	......	do	
Do	3/4	......	1	60	......	do	
Verbena (lemon)	1/2	......	1	64	......	Tender growth burned.	
Vinca major variegata	1/2	......	1	58	......	No burning	
Do	3/4	......	1	56	......	do	
Do	......	5	3/4	66	......	do	
Vinca rosea	1/2	......	1	60	......	do	
Do	3/4	......	1	60	......	do	
Wandering Jew	1/2	......	1	64	......	Severe burning.	
Yucca	......	5 4/5	2/3	....	......	No burning	

PLANTS AND INSECTS FUMIGATED IN FUMIGATION BOX.

To determine the susceptibility of the plants listed in Table II, these plants were fumigated in an air-tight box under favorable conditions. Not only were they fumigated in an inclosure much tighter than a greenhouse, but they also received dosages much in excess of those commonly used in greenhouse work.

TABLE II.—*Plants and insects fumigated with hydrocyanic-acid gas in fumigation box.*

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°*F.*			
Alternanthera sp.		5	½	76		No burning	
Do.		10	1	73		do.	
Amaranthus sp.		3⅘	½			do.	
Arenga mindorensis		5	1	65	Long scale	do.	100 per cent killed.
Atalantia glauca		5	½	76		do.	
Do.		10	1	73		do.	
Banana		10	¾		Citrus mealy bug.	Tender foliage burned.	Do.
Do.		5	1		do.	No burning	95 per cent killed.
Belou glutinosa		10	1	73		do.	
Carnation		5	½	76		Tender foliage burned.	
Catha edgmuthi		2½	¾		Long scale	No burning	60 per cent killed.
Croton	2½		¾	60	do.	do.	Do.
Do.	5		¾	66	do.	do.	100 per cent killed.
Do.	10		¾	68	do.	do.	Do.
Ferns:							
Boston	2½		1	60	Larvæ Florida fern caterpillar.	do.	40 per cent killed.
Do.	5		¾	62	do	do.	100 per cent killed.
Do.	7½		¾	68	do.	do.	Do.
Do.	10		1	68	do.	Tender growth burned.	Do.
Do.		5	½	76	Aspidistra scale.	No burning	All stages except egg killed.
Adiantum cuneatum	2½		1	60	Larvæ Florida fern caterpillar.	do.	40 per cent killed.
Do.	5		¾	62	do.	do.	100 per cent killed.
Do.	7½		¾	68	do.	do.	Do.
Do.	10		¾	68	do.	Tender growth burned.	Do.
Nephrolepis whitmanii	5		¾	66	do.	No burning	Do.
Opuntia		5	½			do.	
Do.		10	½			do.	
Orchids (in growing condition):							
Angraecum eburneum	5		1	62	*Diaspis* sp.	Slight burning.	Do.
Cypripedium sp.	5		1	62		No burning	
Coelogyne flaccida	5		1	62	Chaff scale	do.	Do.
Coelia baueriana	5		1	62		do.	
Dendrobium fimbricatum.	5		1	62	*Lepidosaphes* sp.	do.	Do.
Schomburgkia undulata.	5		1	62		do.	
Orchids (dormant):[1]							
Cattleya trianae	20		¾	70		do.	
Cattleya sp.		20	½			do.	
Do.		21	1			do.	
Do.		42	½			Slight burning; plant recovered.	
Osbeckia stellata		5	1	58	Long scale	No burning	Do.
Palms:							
Kentia belmoreana		5	½		Palm mealy bug and palm aphids.	do.	Do.
Areca lutescens		10	1	65	Tessellated scale.	Old foliage burned.	Do.
Corypha elata		5	1	58	Long scale	No burning	Do.
Phoenix sp.		10	1	73		do.	
Pandanus veitchii		10	1	73	Florida red scale.	do.	Do.

[1] Imported orchids without new growths.

In order that there may be no confusion on the part of the reader as to the insects referred to in the tables by their common names, both their common and scientific names are listed herewith:

Greenhouse white fly _Trialeurodes vaporariorum_ (Westw.).
Citrus mealy bug _Pseudococcus citri_ (Risso).
Long-tailed mealy bug _Pseudococcus adonidum_ (L.).
Palm or avocado mealy bag _Pseudococcus nipae_ (Mask.).
Greenhouse Orthezia _Orthezia insignis_ (Dougl.).
Florida red scale _Chrysomphalus ficus_ (Ashm.)
Long scale _Coccus elongatus_ (Sign.).
Soft brown scale _Coccus hesperidum_ (L.).
Palm aphis _Cerataphis latanae_ (Boisd.).
Hemispherical scale _Coccus hemispherica_ (Targ.).
Florida fern caterpillar _Eriopus floridensis_ (Guen.).
Aspidistra scale _Hemichionaspis aspidistrae_ (Sign.).
Tessellated scale _Eucalymnatus tessellatus_ (Sign.).
Azalea Eriococcus _Eriococcus azaleae_ (Horv.).
Azalea lacewing _Stephanitis azaleae._ (Horv.).
Greenhouse thrips _Heliothrips haemorrhoidalis_ (Bouché).
Onion thrips _Thrips tabaci_ (Lind.).
Cottony scale _Pulvinaria_ sp.
Thread scale _Ischnaspis longirostris_ (Sign.).
Avocado white fly _Trialeurodes floridensis_ (Quaint.).
Rose leafhopper _Typhlocyba rosae_ (L.).
Chaff scale _Parlatoria proteus_ (Curt.).

CONCLUSION.

The results indicated in the foregoing pages are for the most part based on the fumigation of commercial houses under commercial conditions. The slight variations in the percentage of insects killed and injury to plants may be accounted for by the tightness or lack of tightness of different houses. It is obvious, therefore, that it is not practicable to give specific directions as to the amount of cyanid to be employed under all conditions. A knowledge of the pests to be controlled and of the condition of the plants and tightness of the house under consideration will render it possible to determine the dosage to be used.

In fumigating a house containing a large variety of plants, using the correct dosage and under proper conditions, it happens occasionally that some plants appear to have been injured. However, this injury is not permanent, as the plants will show new vigorous growth in a short time. Repeated tests have demonstrated thoroughly that the growth of many plants is stimulated by hydrocyanic-acid gas.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 514

Contribution from the Bureau of Crop Estimates.
LEON M. ESTABROOK, Chief.

Washington, D. C. ▼ February 13, 1917

WHEAT, YIELDS PER ACRE AND PRICES, BY STATES, 50 YEARS 1866-1915.

The year 1915 completes the first 50 years of continuous reports by the United States Department of Agriculture of the yield and value of important crops in the United States, by States. The figures relating to wheat have been assembled in this circular for reference and as an historical record of one phase of American agriculture.

In the following pages the figures under yield represent bushels per acre; under price, the prevailing price paid to producers on or about December 1; and under value, the product of the given yield and price figures.

The States included in the several divisions on pages 2 and 3 are: *North Atlantic*—Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania; *North Central, East*—Ohio, Indiana, Illinois, Michigan, and Wisconsin; *North Central, West*—Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas; *South Atlantic*—Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida; *South Central*—Kentucky, Tennessee, Alabama, Mississippi, Louisiana, Texas, Oklahoma, and Arkansas; *Far West*—Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Idaho, Washington, Oregon, and California.

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Wheat, yields per acre and prices, by States.

Year.	United States.			North Atlantic.			North Central, East.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.	*Cents.*		*Bush.*	*Cents.*		*Bush.*	*Cents.*	
1866	9.9	152.7	$15.05	13.2	186.7	$24.56	9.6	146.2	$14.03
1867	11.6	145.2	16.83	13.2	180.8	23.94	11.6	149.9	17.39
1868	12.1	108.5	13.17	13.4	151.5	20.37	12.1	100.6	12.21
1869	13.6	76.5	10.38	15.4	105.7	16.27	13.8	67.8	9.38
1870	12.4	94.4	11.73	12.7	120.0	15.19	12.6	89.1	11.24
1871	11.6	114.5	13.24	16.6	133.2	22.06	12.8	109.8	14.00
1872	12.0	111.4	13.35	11.7	148.4	17.31	12.5	112.5	14.06
1873	12.7	106.9	13.56	14.1	142.6	20.15	13.1	106.8	13.99
1874	12.3	86.3	10.65	15.1	111.9	16.94	12.7	85.2	10.80
1875	11.1	89.5	9.91	11.8	114.4	13.52	11.1	86.2	9.54
1876	10.5	97.0	10.16	13.8	117.4	16.15	10.4	95.8	10.00
1877	13.9	105.7	14.65	14.7	128.2	18.83	15.6	108.0	16.90
1878	13.1	77.6	10.15	16.2	100.0	16.21	15.5	79.4	12.33
1879	13.8	110.8	15.27	15.0	135.0	20.28	18.3	113.6	20.72
1880	13.1	95.1	12.48	15.3	113.0	17.29	15.9	98.3	15.71
1881	10.2	119.2	12.12	13.0	136.2	17.76	10.8	125.2	13.47
1882	13.6	88.4	12.02	14.3	108.0	15.43	16.1	90.0	14.53
1883	11.6	91.1	10.52	12.4	109.9	13.61	11.1	94.4	10.47
1884	13.0	64.5	8.38	14.5	86.9	12.59	13.8	68.7	9.45
1885	10.4	77.1	8.05	11.6	97.0	11.22	11.9	84.4	10.08
1886	12.4	68.7	8.54	14.0	84.8	11.91	14.4	71.2	10.27
1887	12.1	68.1	8.25	11.4	82.5	9.42	13.4	71.8	9.60
1888	11.1	92.6	10.32	13.7	108.5	14.84	12.0	95.4	11.47
1889	12.9	69.8	8.98	12.8	87.5	11.22	14.9	72.2	10.76
1890	11.1	83.8	9.28	12.8	99.9	12.82	11.7	88.4	10.38
1891	15.3	83.9	12.86	15.9	100.6	16.01	17.5	88.1	15.40
1892	13.4	62.4	8.35	15.0	82.4	12.38	10.4	64.6	9.40
1893	11.4	53.8	6.16	14.2	68.3	9.68	13.6	54.8	7.46
1894	13.2	49.1	6.48	15.0	57.9	8.70	18.0	47.8	8.62
1895	13.7	50.9	6.99	16.7	66.1	11.07	11.8	57.2	6.76
1896	12.4	72.6	8.97	14.6	84.7	12.38	11.2	77.5	8.66
1897	13.4	80.8	10.86	19.9	91.0	18.12	13.6	87.8	11.95
1898	15.3	58.2	8.92	18.2	69.2	12.60	16.2	63.3	10.26
1899	12.3	58.4	7.17	14.6	70.0	10.22	11.4	63.7	7.28
1900	12.3	61.9	7.61	14.6	73.3	10.73	9.1	66.6	6.06
1901	15.0	62.4	9.37	16.1	74.2	11.95	15.3	69.8	10.70
1902	14.5	63.0	9.14	16.1	74.7	12.00	17.1	66.5	11.38
1903	12.9	69.5	8.96	16.1	79.8	12.82	11.6	77.5	9.00
1904	12.5	92.4	11.58	13.5	108.3	14.60	11.7	104.7	12.27
1905	14.5	74.8	10.83	17.9	86.9	15.59	17.3	80.9	14.00
1906	15.5	66.7	10.37	18.2	77.7	14.17	19.1	70.3	13.44
1907	14.0	87.4	12.26	18.4	96.7	17.76	15.9	89.1	14.20
1908	14.0	92.8	12.97	18.3	99.1	18.09	15.6	97.7	15.26
1909	15.8	98.4	15.58	17.8	109.4	19.46	16.6	108.5	17.99
1910	13.9	88.3	12.28	19.1	93.3	17.78	15.9	88.5	14.11
1911	12.5	87.4	10.96	14.9	93.1	13.88	15.9	89.4	14.20
1912	15.9	76.0	12.12	17.6	95.9	16.91	8.8	92.6	8.19
1913	15.2	79.9	12.16	17.6	91.7	16.18	18.1	87.8	15.88
1914	16.6	98.6	16.41	19.0	105.2	20.01	18.3	102.8	18.82
1915	17.0	91.9	15.58	20.2	103.2	20.87	19.1	101.5	19.38
10-YEAR AVERAGE.									
1866–1875	11.9	108.6	12.79	13.7	139.5	19.03	12.2	105.4	12.66
1876–1885	12.3	92.6	11.38	14.1	113.2	15.94	13.9	95.8	13.37
1886–1895	12.7	68.3	8.62	14.2	83.8	11.80	13.8	71.2	10.01
1896–1905	13.5	69.4	9.34	16.2	81.2	13.10	13.4	75.8	10.16
1906–1915	15.0	86.7	13.07	18.1	96.5	17.51	16.3	92.8	15.15

Wheat, yields per acre and prices, by States—Continued.

Year.	North Central, West.			South Atlantic.			South Central.			Far West.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.	*Cents.*		*Bush.*	*Cents.*		*Bush.*	*Cents.*		*Bush.*	*Cents.*	
1866	16.2	106.4	$17.26	6.6	199.1	$13.24	6.3	145.3	$9.22	......	......	......
1867	12.7	110.6	14.02	8.5	162.3	13.79	8.5	150.8	12.80	16.6	110.0	$18.26
1868	14.6	73.8	10.81	8.1	148.9	12.03	7.3	142.4	10.41	20.0	103.0	20.60
1869	14.5	47.4	6.86	10.0	107.6	10.78	9.5	98.3	9.37	18.8	98.3	18.46
1870	13.6	73.1	9.92	9.2	116.3	10.74	9.5	97.7	9.25	19.6	109.7	21.48
1871	11.6	92.7	10.80	8.2	131.8	10.75	5.8	121.9	7.09	12.2	135.8	16.61
1872	13.0	82.8	10.79	8.6	141.5	12.17	10.7	122.7	13.18	13.1	108.2	14.15
1873	14.6	78.4	11.42	8.2	142.4	11.62	8.4	121.3	10.17	14.6	124.8	18.17
1874	12.6	64.5	8.11	8.8	113.0	9.97	9.8	99.7	9.75	14.1	95.8	13.54
1875	12.0	70.7	8.51	8.3	114.2	9.50	9.6	92.9	8.96	12.2	111.8	13.69
1876	9.3	80.8	7.50	9.0	111.5	10.04	9.2	91.3	8.44	13.8	107.3	14.83
1877	15.3	87.2	13.32	10.8	122.5	13.21	9.7	103.1	10.00	11.6	122.2	14.17
1878	11.8	54.9	6.48	8.6	96.9	8.36	7.7	85.4	6.54	15.8	91.4	14.43
1879	11.7	93.2	10.86	10.2	129.3	13.20	9.1	111.1	10.09	13.9	114.8	16.00
1880	11.4	82.4	9.35	9.4	111.0	10.45	7.2	98.6	7.13	16.2	91.2	14.79
1881	8.7	107.1	9.31	8.5	139.3	11.79	7.2	137.0	9.85	14.9	101.4	15.11
1882	13.0	75.3	9.78	9.7	105.7	10.23	9.8	93.0	9.11	14.0	91.1	12.77
1883	13.3	78.3	10.40	8.3	109.9	9.10	6.7	96.9	6.51	14.4	96.5	13.86
1884	14.0	50.0	6.98	8.4	86.3	7.27	8.6	79.2	6.80	14.4	66.1	9.51
1885	11.0	66.1	72.6	6.0	98.0	5.85	5.1	90.7	4.61	12.3	69.9	8.62
1886	12.4	57.5	7.13	7.8	86.9	6.79	8.8	79.8	7.01	12.7	71.1	9.05
1887	12.3	57.1	7.02	8.1	85.0	6.84	9.1	77.5	7.03	13.8	71.7	9.86
1888	10.2	88.6	9.03	8.3	101.6	8.59	9.0	96.5	8.68	14.3	82.5	11.77
1889	12.8	61.0	7.79	8.3	86.4	7.14	8.9	76.9	6.85	14.4	70.5	10.15
1890	11.3	77.1	8.68	6.9	96.6	6.62	7.4	95.7	7.10	13.7	76.6	10.49
1891	16.0	74.9	11.98	9.4	101.0	9.54	10.8	91.8	9.93	15.1	88.0	13.30
1892	13.4	54.3	7.27	9.5	79.0	7.52	10.7	69.9	7.51	14.4	65.4	9.41
1893	9.2	45.5	4.17	10.4	71.6	7.46	10.1	58.2	5.90	15.0	53.3	8.00
1894	11.1	45.6	5.05	9.5	59.5	5.62	11.3	52.0	5.85	13.8	52.0	7.15
1895	15.4	42.1	6.49	9.9	68.2	6.73	9.4	60.4	5.65	15.0	55.1	8.25
1896	12.4	64.3	7.98	10.4	83.9	8.76	9.4	74.2	6.99	16.1	77.9	12.52
1897	12.1	74.5	8.98	13.1	93.3	12.24	14.0	87.1	12.18	15.1	75.0	11.28
1898	14.4	51.4	7.40	12.9	72.8	9.39	14.3	61.8	8.83	19.3	60.4	11.62
1899	11.7	52.8	6.16	9.5	73.6	7.02	10.6	64.0	6.77	17.9	56.5	10.10
1900	11.6	58.0	6.70	12.4	77.5	9.65	14.7	64.8	9.52	15.2	55.9	8.51
1901	14.9	57.9	8.63	11.6	77.1	8.93	12.1	70.4	8.52	19.2	56.4	10.83
1902	14.7	56.7	8.34	8.1	80.2	6.86	9.3	69.2	6.45	16.8	71.7	12.03
1903	13.2	62.4	8.23	8.8	85.4	7.49	11.4	73.3	8.36	16.9	76.4	12.92
1904	12.0	86.4	10.38	10.5	112.1	11.82	11.4	103.9	11.83	18.1	83.6	15.10
1905	14.2	70.0	9.94	11.0	89.6	9.86	8.8	82.8	7.29	18.2	70.3	12.82
1906	14.2	61.4	8.69	12.4	82.7	10.22	12.8	69.2	8.87	20.8	67.4	14.06
1907	12.2	85.6	10.44	13.1	101.2	13.28	9.7	91.3	8.86	22.6	80.6	18.19
1908	12.7	90.3	11.52	12.3	104.4	12.81	11.1	94.9	10.51	20.2	85.7	17.34
1909	15.0	93.9	14.06	11.9	116.2	13.86	11.6	108.0	12.51	23.3	93.3	21.77
1910	11.7	87.6	10.25	13.5	100.2	13.58	14.4	92.1	13.30	19.5	82.2	16.07
1911	9.7	89.5	8.66	12.6	97.7	12.34	10.2	94.7	9.64	23.1	74.5	17.20
1912	16.2	72.0	11.65	12.1	101.9	12.34	12.2	87.3	10.67	24.1	70.5	17.00
1913	13.4	75.6	10.15	12.9	98.6	12.77	12.5	91.0	11.37	22.8	72.7	16.58
1914	15.1	97.0	14.62	15.7	111.0	17.38	16.7	96.6	16.18	22.5	95.4	21.48
1915	16.0	88.0	14.07	13.2	112.8	14.90	12.3	98.9	12.21	24.9	81.9	20.42
10-YEAR AVERAGE.												
1866–1875	13.5	80.0	10.85	8.4	137.7	11.46	8.5	119.3	10.02	15.7	110.8	17.22
1876–1885	12.0	77.5	9.12	8.9	111.0	9.95	8.0	98.6	7.91	14.1	95.2	13.41
1886–1895	12.4	60.4	7.46	8.8	83.6	7.28	9.6	75.9	7.15	14.2	68.6	9.74
1896–1905	13.1	63.4	8.27	10.8	84.6	9.20	11.6	75.2	8.67	17.3	68.4	11.77
1906–1915	13.6	84.1	11.41	13.0	102.7	13.35	12.4	92.4	11.41	22.4	80.4	18.01

Wheat, yields per acre and prices, by States—Continued.

Year.	Maine.			New Hampshire.			Vermont.			Massachusetts.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	12.7	$1.99	$25.27	16.2	$1.79	$29.00	20.2	$1.86	$37.57	24.4	$1.93	$47.09
1867	10.6	2.00	21.20	12.1	2.07	25.05	15.8	1.98	31.28	16.0	2.01	32.16
1868	10.0	1.79	17.90	11.7	1.80	21.06	16.0	1.68	26.88	15.5	1.79	27.74
1869	15.4	1.45	22.33	17.5	1.47	25.72	18.0	1.24	22.32	18.0	1.39	25.02
1870	14.8	1.60	23.68	14.8	1.43	21.16	16.8	1.46	24.53	17.6	1.57	27.63
1871	13.0	1.62	21.06	15.2	1.55	23.56	16.6	1.46	24.24	18.2	1.51	27.48
1872	16.0	1.70	27.20	16.5	1.63	26.90	16.0	1.54	24.64	17.4	1.73	30.10
1873	11.0	1.75	19.25	15.0	1.73	25.95	16.0	1.54	24.64	19.0	1.53	29.07
1874	15.0	1.39	20.85	16.0	1.40	22.40	17.0	1.29	21.93	14.5	1.31	19.00
1875	14.0	1.43	20.02	17.0	1.43	24.31	17.5	1.35	23.62	16.0	1.19	19.04
1876	12.0	1.45	17.40	15.0	1.42	21.30	14.7	1.31	19.26	18.0	1.19	21.42
1877	14.0	1.56	21.84	17.0	1.56	26.52	19.0	1.41	26.79	22.0	1.46	32.12
1878	14.0	1.31	18.34	14.0	1.48	20.72	17.0	1.15	19.55	22.0	1.50	33.00
1879	16.0	1.44	23.04	11.7	1.50	17.55	15.2	1.39	21.13	18.0	1.50	27.00
1880	12.0	1.47	17.64	14.0	1.40	19.60	15.0	1.33	19.95	17.0	1.30	22.10
1881	14.1	1.56	22.00	15.2	1.56	23.71	18.0	1.47	26.46	15.8	1.50	23.70
1882	11.7	1.40	16.38	12.9	1.35	17.42	17.9	1.27	22.73	17.0	1.45	24.65
1883	14.2	1.40	19.88	15.8	1.38	21.80	16.4	1.24	20.34	16.7	1.45	24.22
1884	15.0	1.25	18.75	14.7	1.20	17.64	16.8	1.05	17.64	17.8	1.12	19.94
1885	13.8	1.25	17.25	15.4	1.24	19.10	17.7	1.11	19.65	15.7	1.25	19.62
1886	14.4	1.20	17.28	15.2	1.18	17.94	19.0	1.10	20.90	15.7	1.00	15.70
1887	12.2	1.05	12.81	10.5	1.04	10.92	15.0	.96	14.40	14.8	1.00	14.80
1888	14.5	1.20	17.40	14.6	1.20	17.52	16.7	1.18	19.71	......	......	......
1889	14.2	1.00	14.20	15.4	1.00	15.40	16.5	.95	15.68	......	......	......
1890	13.5	1.15	15.52	15.3	1.15	17.60	17.2	1.11	19.09	......	......	......
1891	16.3	1.10	17.93	16.5	1.15	18.98	17.5	1.14	19.95	......	......	......
1892	16.7	1.02	17.03	16.3	1.00	16.30	17.2	.96	16.51	......	......	......
1893	16.0	1.02	16.32	15.0	.85	12.75	16.8	.85	14.28	......	......	......
1894	21.1	.79	16.67	20.0	.80	16.00	22.7	.67	15.21	......	......	......
1895	19.2	.82	15.74	19.3	.76	14.67	29.0	.69	20.01	......	......	......
1896	22.0	.84	18.48	21.0	1.00	21.00	24.5	.93	22.78	......	......	......
1897	16.5	1.06	17.49	16.0	1.10	17.60	17.0	1.04	17.68	......	......	......
1898	19.5	.89	17.36	19.0	.92	17.48	22.5	.90	20.25	......	......	......
1899	22.5	.91	20.48	17.2	.95	16.34	22.0	.85	18.70	......	......	......
1900	19.5	.90	17.55	16.3	.92	15.00	23.5	.78	18.33	......	......	......
1901	23.9	.97	23.18	......	......	......	18.7	.94	17.58	......	......	......
1902	25.3	.92	23.28	......	......	......	18.8	1.09	20.49	......	......	......
1903	25.5	.98	24.99	......	......	......	20.9	.95	19.86	......	......	......
1904	23.3	1.04	24.23	......	......	......	25.1	1.13	28.36	......	......	......
1905	23.0	1.06	24.38	......	......	......	18.8	.90	16.92	......	......	......
1906	24.8	1.01	25.05	......	......	......	22.3	.86	19.18	......	......	......
1907	26.2	1.01	26.46	......	......	......	23.0	1.00	23.00	......	......	......
1908	23.5	1.04	24.44	......	......	......	23.0	.99	22.77	......	......	......
1909	25.5	1.10	28.05	......	......	......	25.0	1.20	30.00	......	......	......
1910	29.7	1.02	30.29	......	......	......	29.3	1.03	30.18	......	......	......
1911	21.0	1.10	23.10	......	......	......	27.8	.99	27.52	......	......	......
1912	23.5	1.03	24.20	......	......	......	25.0	.98	24.50	......	......	......
1913	25.5	1.01	25.76	......	......	......	24.5	1.00	24.50	......	......	......
1914	27.0	1.09	29.43	......	......	......	29.0	1.00	29.00	......	......	......
1915	28.0	1.12	31.36	......	......	......	30.0	1.07	32.10	......	......	......
10-YEAR AVERAGE.												
1866–1875	13.2	1.67	21.88	15.2	1.63	24.51	17.0	1.54	26.16	17.7	1.60	28.43
1876–1885	13.7	1.41	19.25	14.6	1.41	20.54	16.8	1.27	21.35	18.0	1.37	24.78
1886–1895	15.8	1.04	16.09	15.8	1.01	15.80	18.8	.96	17.57	......	......	......
1896–1905	22.1	.96	21.14	......	......	......	21.2	.95	20.10	......	......	......
1906–1915	25.5	1.05	26.81	......	......	......	25.9	1.01	26.28	......	......	......

Wheat, yields per acre and prices, by States—Continued.

Year.	Rhode Island.			Connecticut.			New York.			New Jersey.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	15.0	$1.95	$29.25	17.3	$1.97	$34.08	15.2	$1.86	$28.27	13.5	$2.04	$27.54
1867	16.9	1.95	32.96	17.5	1.88	32.90	14.5	1.89	27.40	14.0	1.85	25.90
1868	14.3	1.64	23.45	15.5	1.49	23.10	14.6	1.55	22.63	13.9	1.57	21.82
1869	17.0	1.27	21.59	17.5	1.11	19.42	16.0	1.09	17.44	16.5	1.06	17.49
1870	17.6	15.7	27.63	17.8	1.36	24.21	13.8	1.27	17.53	12.8	1.28	16.38
1871	18.0	1.48	26.64	17.0	1.39	23.63	17.2	1.36	23.39	18.0	1.38	24.84
1872				17.0	1.46	24.82	12.5	1.46	18.25	13.5	1.53	20.66
1873				18.0	1.52	27.36	13.5	1.47	19.84	16.2	1.52	24.62
1874				18.0	1.31	23.58	15.6	1.14	17.78	15.5	1.17	18.14
1875				16.0	1.16	18.56	8.0	1.14	9.12	12.0	1.19	14.28
1876				14.5	1.19	17.26	15.0	1.20	18.00	13.6	1.21	16.46
1877				17.0	1.41	23.97	18.0	1.19	21.42	13.8	1.39	19.18
1878				13.0	1.02	13.26	19.0	1.02	19.38	15.0	1.06	15.90
1879				18.0	1.50	27.00	15.0	1.40	21.00	12.3	1.38	16.97
1880				18.0	1.40	25.20	16.0	1.17	18.72	15.5	1.17	18.14
1881	10.4	1.50	15.60	17.7	1.42	25.13	13.9	1.37	19.04	12.7	1.43	18.16
1882				20.3	1.20	24.36	15.7	1.10	17.27	13.6	1.12	15.23
1883	15.3	1.40	21.42	15.8	1.25	19.75	10.3	1.11	11.43	13.4	1.10	14.74
1884				16.4	1.00	16.40	16.5	.85	14.02	13.0	.90	11.70
1885				14.1	1.05	14.80	15.4	.96	14.78	9.7	.95	9.22
1886				16.4	.98	16.07	16.3	.84	13.69	15.6	.86	13.42
1887				17.0	.99	16.83	15.2	.82	12.46	10.2	87	8.87
1888				14.9	1.20	17.88	14.1	1.10	15.51	12.6	1.10	13.86
1889				15.5	.92	14.26	13.8	.90	12.42	12.2	.92	11.22
1890				16.0	1.10	17.66	14.5	1.00	14.50	12.1	1.00	12.10
1891				17.0	1.06	18.02	16.6	1.00	16.60	15.3	1.04	15.91
1892							16.2	.85	13.77	14.3	.83	11.87
1893							14.5	.76	11.02	14.5	.70	10.15
1894							14.8	.62	9.18	15.3	.61	9.33
1895							18.1	.68	12.31	12.4	.71	8.80
1896							16.0	.88	14.08	15.3	.89	13.62
1897				20.0	1.00	20.00	21.4	.90	19.26	18.5	.93	17.20
1898				20.0	.88	17.60	21.2	.72	15.26	17.4	.73	12.70
1899				18.3	.95	17.38	18.5	.80	14.80	14.5	.75	10.88
1900				20.8	.82	17.06	17.7	.77	13.63	19.1	.74	14.13
1901							13.1	.82	10.74	16.8	.72	12.10
1902							16.8	.79	13.27	16.0	.76	12.16
1903							17.8	.81	14.42	14.0	.82	11.48
1904							11.3	1.09	12.32	13.3	1.10	14.63
1905							21.0	.86	18.06	16.4	.88	14.43
1906							20.0	.82	16.40	18.3	.80	14.64
1907							17.3	.99	17.13	18.5	.98	18.13
1908							17.5	.99	17.32	17.3	1.01	17.47
1909							21.0	1.11	23.31	17.9	1.09	19.51
1910							23.7	.96	22.75	18.5	.98	18.13
1911							19.5	.95	18.52	17.4	.96	16.70
1912							16.0	.99	15.84	18.5	.98	18.13
1913							20.0	.93	18.60	17.6	.96	16.90
1914							22.5	1.08	24.30	18.0	1.09	19.62
1915							25.0	1.01	25.25	20.0	1.06	21.20
10-YEAR AVERAGE.												
1866–1875				17.2	1.46	25.17	14.1	1.42	20.16	14.6	1.46	21.17
1876–1885				16.5	1.24	20.71	15.5	1.14	17.51	13.3	1.17	15.57
1886–1895							15.4	.86	13.15	13.4	.86	11.55
1896–1905							17.5	.84	14.58	16.1	.83	13.33
1906–1915							20.2	.98	19.94	18.2	.99	18.04

Wheat, yields per acre and prices, by States—Continued.

Year.	Pennsylvania.			Delaware.			Maryland.			Virginia.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	11.0	$1.86	$20.46	8.0	$2.09	$16.72	9.7	$2.04	$19.79	6.7	$1.98	$13.27
1867	12.5	1.74	21.75	9.3	1.70	15.81	11.0	1.74	19.14	8.0	1.52	12.16
1868	12.8	1.47	18.82	12.0	1.41	16.92	10.2	1.56	15.91	8.4	1.41	11.84
1869	14.8	1.01	14.95	13.5	1.01	13.64	11.8	1.03	12.15	10.5	.96	10.08
1870	12.0	1.14	13.68	10.0	1.12	11.20	9.7	1.15	11.16	9.6	1.11	10.66
1871	16.2	1.30	21.06	11.5	1.37	15.76	12.0	1.37	16.44	8.0	1.25	10.00
1872	10.8	1.48	15.98	9.2	1.42	13.06	8.5	1.49	12.66	8.4	1.38	11.59
1873	14.2	1.38	19.60	11.0	1.55	17.05	11.3	1.42	16.05	7.5	1.34	10.05
1874	14.8	1.09	16.13	11.0	1.18	12.98	10.7	1.10	11.77	7.8	1.06	8.27
1875	13.8	1.12	15.46	13.5	1.22	16.47	11.0	1.11	12.21	8.0	1.05	8.40
1876	13.2	1.15	15.18	16.0	1.16	18.56	12.5	1.16	14.50	8.5	1.04	8.84
1877	13.0	1.32	17.16	13.5	1.36	18.36	13.8	1.31	18.08	10.4	1.15	11.96
1878	15.0	.97	14.55	13.0	1.00	13.00	13.0	.98	12.74	7.2	.89	6.41
1879	15.3	1.32	20.20	13.0	1.38	17.94	14.4	1.42	20.45	9.2	1.27	11.68
1880	15.0	1.09	16.35	15.4	1.15	17.71	14.0	1.14	15.96	9.5	1.05	9.98
1881	12.5	1.34	16.75	10.1	1.40	14.14	11.7	1.35	15.80	8.0	1.33	10.64
1882	13.6	1.05	14.28	12.2	1.07	13.05	14.0	1.07	14.98	9.0	1.06	9.54
1883	13.2	1.08	14.26	10.3	1.11	11.43	12.1	1.06	12.83	9.0	1.05	9.45
1884	13.6	.86	11.70	10.6	.85	9.01	12.8	.83	10.62	8.0	.80	6.40
1885	9.7	.96	9.31	10.7	.95	10.16	9.5	.91	8.64	4.4	.93	4.09
1886	12.7	.83	10.54	12.4	.84	10.42	12.3	.82	10.09	8.2	.81	6.64
1887	9.7	.81	7.86	9.8	.84	8.23	10.3	.83	8.55	7.6	.81	6.16
1888	13.5	1.07	14.44	12.6	1.00	12.60	13.7	1.00	13.70	8.3	1.00	8.30
1889	12.3	.85	10.46	11.6	.80	9.28	11.3	.81	9.15	8.4	.86	7.22
1890	12.0	.99	11.88	9.7	.96	9.31	11.6	.92	10.67	7.0	.96	6.72
1891	15.6	1.00	15.60	12.8	1.00	12.80	15.0	1.00	15.00	9.0	1.00	9.00
1892	14.6	.81	11.83	13.0	.75	9.75	13.2	.74	9.77	9.5	.76	7.22
1893	14.0	.65	9.10	14.7	.60	8.82	13.5	.76	10.26	11.2	.63	7.06
1894	15.0	.56	8.40	13.0	.55	7.15	15.3	.54	8.26	9.5	.56	5.32
1895	16.6	.65	10.79	11.6	.64	7.42	17.0	.64	10.88	9.3	.65	6.04
1896	14.0	.83	11.62	18.0	.87	15.66	17.0	.88	14.96	9.3	.80	7.44
1897	19.7	.91	17.93	21.5	.94	20.21	19.2	.93	17.86	12.0	.92	11.04
1898	17.5	.68	11.90	13.3	.69	9.18	15.3	.70	10.71	14.1	.66	9.31
1899	13.6	.66	8.98	12.8	.68	8.70	14.1	.68	9.59	8.4	.69	5.80
1900	13.5	.72	9.72	20.3	.70	14.21	19.5	.71	13.84	11.9	.72	8.57
1901	17.1	.72	12.31	18.5	.71	13.14	17.2	.71	12.21	10.9	.73	7.96
1902	15.8	.73	11.53	16.5	.75	12.38	14.7	.72	10.58	5.7	.79	4.50
1903	15.6	.79	12.32	10.2	.78	7.96	12.5	.79	9.88	8.7	.84	7.31
1904	14.1	1.08	15.23	14.9	1.08	16.09	13.4	1.06	14.20	10.2	1.09	11.12
1905	17.1	.87	14.88	13.8	.82	11.32	16.3	.82	13.37	11.4	.88	10.03
1906	17.7	.76	13.45	16.0	.71	11.36	16.0	.71	11.36	12.5	.81	10.12
1907	18.6	.96	17.86	20.5	.97	19.88	19.0	.96	18.24	12.5	.98	12.25
1908	18.5	.99	18.32	15.0	1.00	15.00	16.4	.98	16.07	11.4	1.01	11.51
1909	17.0	1.09	18.53	14.0	1.04	14.56	14.5	1.10	15.95	11.2	1.15	12.88
1910	17.8	.92	16.38	17.0	.90	15.30	17.4	.92	16.01	12.8	.97	12.42
1911	13.5	.92	12.42	16.7	.90	15.03	15.5	.91	14.10	12.0	.96	11.52
1912	18.0	.95	17.10	17.5	.96	16.80	15.0	.95	14.25	11.6	1.01	11.72
1913	17.0	.91	15.47	14.5	.88	12.76	13.3	.89	11.84	13.6	.96	13.06
1914	18.1	1.04	18.82	20.5	1.09	22.34	21.5	1.06	22.79	14.5	1.08	15.66
1915	18.5	1.04	19.24	15.0	1.09	16.35	16.1	1.05	16.90	13.8	1.08	14.90
10-YEAR AVERAGE.												
1866–1875	13.3	1.36	17.79	10.9	1.41	14.96	10.6	1.40	14.73	8.3	1.31	10.63
1876–1885	13.4	1.11	14.97	12.5	1.14	14.34	12.8	1.12	14.46	8.3	1.06	8.90
1886–1895	13.6	.82	11.09	12.1	.80	9.58	13.3	.81	10.63	8.8	.80	6.97
1896–1905	15.8	.80	12.64	16.0	.80	12.88	15.9	.80	12.72	10.3	.81	8.31
1906–1915	17.5	.96	16.76	16.7	.95	15.94	16.5	.95	15.75	12.6	1.00	12.60

Wheat, yields per acre and prices, by States—Continued.

Year.	West Virginia.			North Carolina.			South Carolina.			Georgia.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	....	....	....	5.8	$1.89	$10.96	4.7	$2.22	$10.43	4.0	$1.89	$7.56
1867	10.5	$1.71	$17.96	6.9	1.51	10.42	6.4	1.70	10.88	8.0	1.68	13.44
1868	10.7	1.40	14.98	5.9	1.49	8.79	5.6	1.67	9.35	5.6	1.64	9.18
1869	11.7	1.00	11.70	8.4	1.21	10.16	6.6	1.66	10.96	7.4	1.31	9.69
1870	11.4	1.10	12.54	8.6	1.09	9.37	7.0	1.70	11.90	8.0	1.32	10.56
1871	10.0	1.18	11.80	6.0	1.28	7.68	5.0	1.83	9.15	5.0	1.49	7.45
1872	10.3	1.27	13.08	8.2	1.36	11.15	6.1	1.67	10.19	9.0	1.53	13.77
1873	9.6	1.32	12.67	6.2	1.43	8.87	5.5	2.07	11.38	7.0	1.61	11.27
1874	11.6	.90	10.44	8.0	1.24	9.92	6.3	1.67	10.52	7.3	1.38	10.07
1875	6.8	1.20	8.16	7.5	1.08	8.10	7.0	1.48	10.36	7.5	1.31	9.82
1876	11.0	1.02	11.22	7.3	1.10	8.03	8.0	1.52	12.16	6.0	1.23	7.38
1877	12.2	1.21	14.76	8.3	1.06	8.80	9.9	1.51	14.95	9.5	1.32	12.54
1878	11.5	.86	9.89	6.5	1.00	6.50	5.5	1.30	7.15	7.0	1.18	8.26
1879	13.0	1.08	14.04	7.0	1.28	8.96	8.4	1.57	13.19	9.0	1.26	11.34
1880	12.2	.91	11.10	6.4	1.15	7.36	4.8	1.44	6.91	6.3	1.36	8.57
1881	10.5	1.25	13.12	6.9	1.49	10.28	5.7	1.65	9.40	6.1	1.63	9.94
1882	11.3	.95	10.74	7.7	1.06	8.16	7.5	1.20	9.00	7.5	1.08	8.10
1883	10.0	1.08	10.80	5.9	1.17	6.90	5.2	1.30	6.76	5.1	1.20	6.12
1884	10.5	.80	8.40	6.1	.89	5.43	6.1	1.05	6.40	6.4	1.05	6.72
1885	5.6	1.01	5.66	4.1	1.00	4.10	5.3	1.10	5.83	6.2	1.09	6.76
1886	10.6	.80	8.48	4.6	1.00	4.60	5.0	1.08	5.40	4.4	1.05	4.62
1887	9.4	.76	7.14	7.1	.88	6.25	6.4	.99	6.34	6.6	.95	6.27
1888	9.5	.96	9.12	5.4	1.05	5.67	5.0	1.12	5.60	5.1	1.10	5.61
1889	10.2	.83	8.47	6.2	.90	5.58	6.0	.95	5.70	6.3	.98	6.17
1890	7.7	.95	7.32	4.4	1.00	4.40	4.2	1.05	4.41	4.1	1.10	4.51
1891	10.3	.96	9.89	6.8	1.02	6.94	5.5	1.10	6.05	7.5	1.10	8.25
1892	10.7	.75	8.02	7.1	.89	6.32	6.5	.93	6.04	6.8	.90	6.12
1893	11.5	.72	8.28	8.2	.72	5.90	6.3	.98	6.17	7.2	.90	6.48
1894	12.1	.60	7.26	5.0	.65	3.25	5.6	.87	4.87	6.9	.76	5.24
1895	10.6	.69	7.31	6.9	.72	4.97	6.4	.88	5.63	6.2	.82	5.08
1896	10.3	.78	8.03	7.3	.83	6.06	6.8	.89	6.05	8.0	.89	7.12
1897	13.4	.89	11.93	8.0	.94	7.52	8.7	1.18	10.27	9.4	1.03	9.68
1898	13.8	.71	9.80	9.2	.78	7.18	10.6	.94	9.96	10.0	.98	9.80
1899	9.3	.71	6.60	6.7	.82	5.49	6.5	.99	6.44	6.8	.98	6.66
1900	9.8	.77	7.55	9.6	.82	7.87	9.0	1.01	9.09	9.1	.95	8.64
1901	10.9	.77	8.39	8.7	.82	7.13	8.8	.98	8.62	8.2	.94	7.71
1902	7.7	.82	6.31	5.3	.92	4.88	5.6	1.02	5.71	6.0	.98	5.88
1903	10.2	.85	8.67	5.1	.97	4.95	6.5	1.01	6.56	6.2	.96	5.95
1904	10.1	1.09	11.01	8.6	1.19	10.23	8.1	1.26	10.21	8.8	1.26	11.09
1905	12.3	.89	10.95	6.7	1.02	6.83	6.1	1.11	6.77	6.9	1.07	7.38
1906	12.7	.81	10.29	9.1	.93	8.46	9.3	1.10	10.23	10.0	1.02	10.20
1907	12.2	1.00	12.20	9.5	1.07	10.16	8.5	1.20	10.20	9.0	1.15	10.35
1908	13.0	1.03	13.39	10.0	1.07	10.70	9.0	1.30	11.70	9.2	1.21	11.13
1909	13.0	1.13	14.69	9.5	1.27	12.06	10.0	1.46	14.60	10.0	1.45	14.50
1910	12.5	1.02	12.75	11.4	1.10	12.54	11.0	1.26	13.86	10.5	1.30	13.65
1911	11.5	1.02	11.73	10.6	1.02	10.81	11.4	1.23	14.02	12.0	1.14	13.68
1912	14.5	1.01	14.64	8.9	1.11	9.88	9.2	1.19	10.95	9.3	1.22	11.35
1913	13.0	1.00	13.00	11.7	1.06	12.40	12.3	1.30	15.99	12.2	1.20	14.64
1914	15.0	1.08	16.20	12.0	1.17	14.04	11.5	1.45	16.68	12.1	1.34	16.21
1915	15.0	1.08	16.20	10.9	1.20	13.08	10.8	1.38	14.90	11.0	1.29	14.19
10-YEAR AVERAGE.												
1866–1875	[1] 10.3	[1] 1.23	[1] 12.59	7.2	1.36	9.54	6.0	1.77	10.51	6.9	1.52	10.28
1876–1885	10.8	1.02	10.97	6.6	1.12	7.45	6.6	1.36	9.18	6.9	1.24	8.57
1886–1895	10.3	.80	8.13	6.2	.88	5.39	5.7	1.00	5.62	6.1	.97	5.84
1896–1905	10.8	.83	8.92	7.5	.91	6.81	7.7	1.04	7.97	7.9	1.00	7.99
1906–1915	13.2	1.02	13.51	10.4	1.10	11.41	10.3	1.29	13.31	10.5	1.23	12.99

[1] 9-year average—1867–1875.

Wheat, yields per acre and prices, by States—Continued.

Year.	Florida.			Ohio.			Indiana.			Illinois.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866				4.2	$1.75	$7.35	5.9	$1.68	$9.91	13.0	$1.34	$17.42
1867	7.9	$1.58	$12.48	11.6	1.69	19.60	10.5	1.58	16.59	11.4	1.41	16.07
1868	9.0	2.05	18.45	13.0	1.23	15.99	11.2	1.12	12.54	11.5	.89	10.24
1869	10.0	1.50	15.00	15.5	.82	12.71	14.4	.74	10.66	11.2	.60	6.72
1870				13.8	.98	13.52	11.0	.90	9.90	12.0	.84	10.08
1871				13.9	1.13	15.71	12.0	1.13	13.56	12.3	1.06	13.04
1872				11.7	1.26	14.74	12.4	1.17	14.51	12.1	1.09	13.19
1873				12.0	1.21	14.52	11.2	1.12	12.54	13.5	1.01	13.64
1874				15.0	.94	14.10	12.2	.85	10.37	11.5	.78	8.97
1875				9.5	.95	9.02	9.0	.85	7.65	10.5	.79	8.30
1876				11.8	1.04	12.27	11.0	.93	10.23	9.3	.85	7.90
1877				15.0	1.21	18.15	14.5	1.10	15.95	16.5	1.01	16.66
1878				18.0	.86	15.48	16.0	.81	12.96	13.6	.75	10.20
1879				19.5	1.20	23.40	20.3	1.17	23.75	18.7	1.07	20.01
1880				17.5	1.02	17.85	16.8	.99	16.63	16.7	.95	15.86
1881	5.1	1.65	8.42	13.3	1.29	17.16	10.8	1.27	13.72	8.2	1.22	10.00
1882	4.4	1.25	5.50	15.1	.95	14.34	16.5	.90	14.85	17.7	.86	15.22
1883				10.0	.99	9.90	10.4	.95	9.88	10.0	.92	9.20
1884				15.3	.75	11.48	12.5	.67	8.38	11.6	.63	7.31
1885				10.2	.91	9.28	10.6	.86	9.12	8.5	.81	6.88
1886				15.0	.74	11.10	14.8	.70	10.36	13.7	.69	9.45
1887				13.1	.75	9.82	13.5	.72	9.72	15.2	.70	10.64
1888				10.8	.97	10.48	10.4	.94	9.78	13.7	.93	12.74
1889				14.6	.76	11.10	14.7	.71	10.44	16.0	.70	11.20
1890				12.5	.91	11.38	11.2	.88	9.86	9.8	.87	8.53
1891				17.1	.92	15.73	18.1	.86	15.57	18.0	.85	15.30
1892				13.6	.68	9.25	14.7	.64	9.41	16.2	.63	10.21
1893				14.5	.57	8.26	14.1	.53	7.47	11.5	.51	5.86
1894				19.0	.49	9.31	18.4	.46	8.46	18.2	.45	8.19
1895				13.3	.60	7.98	9.2	.57	5.24	11.0	.53	5.83
1896				9.0	.78	7.02	9.0	.80	7.20	14.7	.74	10.88
1897				16.9	.88	14.87	13.0	.89	11.57	7.9	.89	7.03
1898				16.9	.66	11.15	15.6	.63	9.83	11.0	.60	6.60
1899				14.2	.64	9.09	9.8	.64	6.27	10.0	.63	6.30
1900				6.0	.71	4.26	5.3	.70	3.71	13.0	.64	8.32
1901				15.3	.71	10.86	15.8	.70	11.06	17.6	.69	12.14
1902				17.1	.71	12.14	16.0	.68	10.88	17.9	.59	10.56
1903				13.7	.80	10.96	10.0	.78	7.80	8.4	.75	6.30
1904				11.5	1.10	12.65	9.2	1.06	9.75	13.8	1.01	13.94
1905				17.1	.82	14.02	18.3	.82	15.01	16.0	.81	12.96
1906				20.4	.71	14.48	20.7	.70	14.49	19.5	.69	13.46
1907				16.3	.92	15.00	14.4	.88	12.67	18.0	.87	15.66
1908				16.0	.99	15.84	16.6	.98	16.27	13.0	.97	12.61
1909				15.9	1.12	17.81	15.3	1.10	16.83	17.4	1.04	18.10
1910				16.2	.90	14.58	15.6	.87	13.57	15.0	.88	13.20
1911				16.0	.91	14.56	14.7	.89	13.08	16.0	.89	14.24
1912				8.0	.98	7.84	8.0	.93	7.44	8.3	.88	7.30
1913				18.0	.90	16.20	18.5	.88	16.28	18.7	.86	16.08
1914				18.5	1.05	19.42	17.4	1.03	17.92	18.5	1.01	18.68
1915				20.3	1.04	21.11	17.2	1.02	17.54	19.0	1.00	19.00
10-YEAR AVERAGE.												
1866–1875				12.0	1.20	13.73	11.0	1.11	11.82	11.9	.98	11.77
1876–1885				14.6	1.02	14.93	13.9	.96	13.55	13.1	.91	11.92
1886–1895				14.4	.74	10.44	13.9	.70	9.63	14.3	.69	9.80
1896–1905				13.8	.78	10.70	12.2	.77	9.31	13.0	.74	9.50
1906–1915				16.6	.95	15.68	15.8	.93	14.61	16.3	.91	14.83

Wheat, yields per acre and prices, by States—Continued.

Year.	Michigan.			Wisconsin.			Minnesota.			Iowa.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	13.8	$1.77	$24.43	14.5	$1.11	$16.10	......	......	......	16.0	$0.99	$15.84
1867	12.4	1.68	20.83	12.3	1.27	15.62	12.5	$1.06	$13.25	12.7	1.02	12.95
1868	12.5	1.22	15.25	13.0	.74	9.62	15.0	.62	9.30	14.5	.71	10.30
1869	15.2	.77	11.70	15.3	.54	8.26	16.3	.47	7.66	13.0	.41	5.33
1870	14.0	.97	13.58	13.4	.81	10.85	15.2	.75	11.40	12.5	.70	8.75
1871	14.0	1.19	16.66	12.2	1.00	12.20	11.0	.90	9.90	10.8	.86	9.29
1872	12.0	1.29	15.48	14.3	.91	13.01	16.5	.74	12.21	12.6	.75	9.45
1873	12.2	1.24	15.13	16.5	.89	14.68	18.3	.74	13.54	13.0	.73	9.49
1874	14.2	.97	13.77	11.5	.75	8.62	13.4	.63	8.44	11.6	.59	6.84
1875	13.5	1.00	13.50	14.0	.79	11.06	17.0	.75	12.75	9.7	.62	6.01
1876	12.0	1.06	12.72	9.0	.93	8.37	8.5	.82	6.97	6.1	.82	5.00
1877	17.5	1.19	20.82	15.0	.90	13.50	18.5	.89	16.46	14.5	.85	12.32
1878	18.3	.85	15.56	12.4	.67	8.31	12.0	.51	6.12	9.4	.50	4.70
1879	19.2	1.17	22.46	12.6	1.04	13.10	12.3	.94	11.56	10.2	.92	9.38
1880	17.0	.97	16.49	9.5	1.00	9.50	13.2	.87	11.48	10.4	.82	8.53
1881	10.9	1.25	13.62	11.3	1.19	13.45	11.4	1.06	12.08	6.6	1.06	7.00
1882	16.3	.90	14.67	14.4	.90	12.96	13.0	.82	10.66	10.3	.70	7.21
1883	14.0	.96	13.44	12.3	.88	10.82	13.0	.80	10.40	11.3	.80	9.04
1884	16.5	.74	12.21	14.0	.60	8.40	15.0	.50	7.50	12.0	.55	6.60
1885	19.3	.84	16.21	11.5	.76	8.74	11.1	.70	7.77	11.3	.67	7.57
1886	16.0	.73	11.68	11.5	.68	7.82	14.0	.61	8.54	12.2	.60	7.30
1887	13.3	.74	9.84	10.3	.64	6.59	11.6	.59	6.84	10.0	.61	6.12
1888	14.6	.98	14.31	11.5	.96	11.04	9.0	.92	8.28	9.8	.85	8.33
1889	14.7	.74	10.88	14.2	.70	9.94	14.6	.67	9.78	13.1	.63	8.25
1890	13.5	.90	12.15	12.2	.83	10.13	12.2	.81	9.88	11.3	.80	9.04
1891	18.8	.91	17.11	13.5	.84	11.34	17.6	.78	13.73	15.3	.81	12.39
1892	14.7	.67	9.85	11.5	.62	7.13	11.6	.61	7.08	11.5	.60	6.90
1893	13.2	.57	7.52	13.3	.54	7.18	9.6	.51	4.90	11.5	.49	5.64
1894	15 8	.52	8.22	16.5	.51	8.42	13.5	.49	6.62	14.8	.50	7.40
1895	13.2	.60	7.92	15.5	.51	7.90	23.0	.44	10.12	19.5	.46	8.97
1896	12.8	.84	10.75	13.3	.70	9.31	14.2	.68	9.66	16.0	.62	9.92
1897	15.6	.87	13.57	12.5	.84	10.50	13.0	.77	10.01	13.0	.75	9.75
1898	20.8	.64	13.31	18.0	.59	10.62	15.8	.54	8.53	16.7	.52	8.68
1899	8.4	.65	5.46	15.5	.61	9.46	13.4	.55	7.37	13.0	.55	7.15
1900	7.6	.69	5.24	15.5	.64	9.92	10.5	.63	6.62	15.6	.59	9.20
1901	11.1	.71	7.88	16.1	.65	10.46	12.9	.60	7.74	16.2	.60	9.72
1902	17.7	.69	12.21	18.1	.64	11.58	13.9	.61	8.48	12.7	.55	6.98
1903	15.5	.77	11.94	15.6	.72	11.23	13.1	.69	9.04	12.4	.62	7.69
1904	9.8	1.08	10.58	15.5	.98	15.19	12.8	.87	11.14	11.6	.90	10.44
1905	18.5	.79	14.62	16.6	.76	12.62	13.3	.71	9.44	14.2	.71	10.08
1906	13.1	.72	9.43	16.3	.72	11.74	10.9	.65	7.08	15.7	.64	10.05
1907	14.5	.91	13.20	14.1	.92	12.97	13.0	.92	11.96	13.4	.82	10.99
1908	18.0	.97	17.46	18.2	.92	16.74	12.8	.94	12.03	17.2	.88	15.14
1909	18.8	1.12	21.06	19.5	.96	18.72	16.8	.96	16.13	17.0	.93	15.81
1910	18.0	.89	16.02	19.3	.92	17.76	16.0	.94	15.04	21.0	.85	17.85
1911	18.0	.88	15.84	15.9	.90	14.31	10.1	.92	9.29	16.4	.88	14.43
1912	10.0	.96	9.60	19.0	.83	15.77	15.5	.73	11.32	19.8	.78	15.44
1813	15.3	.89	13.62	19.3	.82	15.83	16.2	.76	12.31	20.6	.76	15.66
1914	19.7	1.03	20.29	19.1	1.00	19.10	10.6	1.02	10.81	18.6	.96	17.86
1915	21.3	1.01	21.51	22.7	.95	21.56	17.0	.90	15.30	20.0	.87	17.40
10-YEAR AVERAGE.												
1866–1875	13.4	1.21	16.03	13.7	.88	12.00	15.0	.74	10.94	12.6	.74	9.42
1876–1885	16.1	.99	15.82	12.2	.89	10.72	12.8	.79	10.10	10.2	.77	7.74
1886–1895	14.8	.74	10.95	13.0	.68	8.75	13.7	.64	8.58	12.9	.64	8.03
1896–1905	13.8	.77	10.56	15.7	.71	11.09	13.3	.66	8.80	14.1	.64	8.96
1906–1915	16.7	.94	15.80	18.3	.89	16.45	13.9	.87	12.13	18.0	.84	15.06

Wheat, yields per acre and prices, by States—Continued.

Year.	Missouri.			North Dakota.			South Dakota.			Nebraska.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	16.5	$1.40	$23.10	......	......	......	......	......	......	26.0	$0.86	$22.36
1867	12.4	1.43	17.73	......	......	......	......	......	......	15.0	.95	14.25
1868	14.0	1.11	15.54	......	......	......	......	......	......	15.5	.71	11.00
1869	14.1	.63	8.88	......	......	......	......	......	......	17.8	.40	7.12
1870	13.0	.82	10.66	......	......	......	......	......	......	14.4	.57	8.21
1871	13.4	1.04	13.94	......	......	......	......	......	......	10.3	.81	8.34
1872	8.8	1.25	11.00	......	......	......	......	......	......	12.2	.69	8.42
1873	12.8	1.04	13.31	......	......	......	......	......	......	15.5	.69	10.70
1874	13.5	.75	10.12	......	......	......	......	......	......	11.6	.54	6.26
1875	9.0	.83	7.47	......	......	......	......	......	......	9.8	.56	5.49
1876	12.4	.82	10.17	......	......	......	......	......	......	11.5	.72	8.28
1877	14.0	.97	13.58	......	......	......	......	......	......	15.0	.81	12.15
1878	11.0	.67	7.37	......	......	......	......	......	......	13.1	.49	6.42
1879	14.0	1.01	14.14	......	......	......	......	......	......	11.3	.84	9.49
1880	13.4	.89	11.93	......	......	......	......	......	......	8.5	.73	6.20
1881	8.6	1.19	10.23	......	......	......	......	......	......	7.1	.97	6.89
1882	11.8	.85	10.03	[1] 15.9	$0.80	$12.72	[1] 15.9	$0.80	$12.72	11.0	.67	7.37
1883	10.1	.88	8.89	[1] 16.0	.72	11.52	[1] 16.0	.72	11.52	15.5	.70	10.85
1884	11.8	.62	7.32	[1] 14.5	.46	6.67	[1] 14.5	.46	6.67	14.5	.42	6.09
1885	7.4	.77	5.70	[1] 12.8	.63	8.06	[1] 12.8	.63	8.06	11.3	.57	6.44
1886	13.2	.63	8.32	[1] 11.5	.52	5.98	[1] 11.5	.52	5.98	11.0	.47	5.17
1887	16.2	.62	10.04	[1] 14.3	.52	7.44	[1] 14.3	.52	7.44	10.1	.53	5.35
1888	12.0	.88	10.56	[1] 9.7	.91	8.83	[1] 9.7	.91	8.83	9.3	.83	7.72
1889	13.0	.64	8.32	[1] 9.4	.60	5.64	[1] 9.4	.60	5.64	12.0	.52	6.24
1890	11.0	.83	9.13	[1] 9.6	.70	6.72	[1] 9.6	.70	6.72	10.8	.76	8.21
1891	13.6	.80	10.88	17.8	.70	12.46	15.2	.72	10.94	15.0	.73	10.95
1892	12.5	.58	7.25	12.2	.52	6.34	12.5	.51	6.38	12.5	.50	6.25
1893	9.5	.48	4.56	9.6	.43	4.13	8.5	.44	3.74	8.7	.40	3.48
1894	15.3	.43	6.58	11.8	.43	5.07	6.6	.46	3.04	7.0	.49	3.43
1895	12.0	.51	6.12	21.0	.38	7.98	12.0	.38	4.56	12.0	.40	4.80
1896	11.7	.70	8.19	11.8	.64	7.55	11.2	.62	6.94	14.0	.58	8.12
1897	9.0	.85	7.65	10.3	.74	7.62	8.0	.69	5.52	14.5	.69	10.00
1898	9.8	.59	5.78	14.4	.51	7.34	12.4	.50	6.20	16.4	.47	7.71
1899	9.9	.62	6.14	12.8	.51	6.53	10.7	.50	5.35	10.3	.49	5.05
1900	12.5	.63	7.88	4.9	.58	2.84	6.9	.58	4.00	12.0	.53	6.36
1901	15.9	.69	10.97	13.1	.54	7.07	12.9	.53	6.84	17.1	.54	9.23
1902	19.9	.58	11.54	15.9	.58	9.22	12.2	.57	6.95	20.9	.49	10.24
1903	8.7	.71	6.18	12.7	.63	8.00	13.8	.62	8.56	15.7	.54	8.48
1904	11.7	.96	11.23	11.8	.81	9.56	9.6	.79	7.58	13.6	.87	11.83
1905	12.4	.79	9.80	14.0	.69	9.66	13.7	.67	9.18	19.4	.66	12.80
1906	14.8	.67	9.92	13.0	.63	8.19	13.4	.61	8.17	22.0	.57	12.54
1907	13.2	.84	11.09	10.0	.87	8.70	11.2	.89	9.97	18.1	.79	14.30
1908	10.0	.93	9.30	11.6	.92	10.67	12.8	.92	11.78	17.2	.84	14.45
1909	14.7	1.05	15.44	13.7	.92	12.60	14.1	.90	12.69	18.8	.89	16.73
1910	13.8	.87	12.01	5.0	.90	4.50	12.8	.89	11.39	16.2	.80	12.96
1911	15.7	.88	13.82	8.0	.89	7.12	4.0	.91	3.64	13.4	.87	11.66
1912	12.5	.90	11.25	18.0	.69	12.42	14.2	.69	9.80	17.6	.69	12.14
1913	17.1	.84	14.36	10.5	.73	7.66	9.0	.71	6.39	17.9	.71	12.71
1914	17.0	.98	16.66	11.2	1.01	11.31	9.1	.94	8.55	18.6	.95	17.67
1915	12.3	.98	12.05	18.2	.87	15.83	17.1	.86	14.71	18.3	.84	15.37
10-YEAR AVERAGE.												
1866–1875	12.8	1.03	13.18	......	......	......	......	......	......	14.8	.68	10.22
1876–1885	11.4	.87	9.94	......	......	......	......	......	......	11.9	.69	8.02
1886–1895	12.8	.64	8.18	12.7	.57	7.06	10.9	.58	6.33	10.8	.56	6.16
1896–1905	12.2	.71	8.54	12.2	.62	7.54	11.1	.61	6.71	15.4	.59	8.98
1906–1915	14.1	.89	12.59	11.9	.84	9.90	11.8	.83	9.71	17.8	.80	14.05

[1] Dakota Territory.

Wheat, yields per acre and prices, by States—Continued.

Year.	Kansas.			Kentucky.			Tennessee.			Alabama.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	21.4	$1.33	$28.46	6.5	$1.60	$10.40	5.3	$1.54	$8.16	5.7	$1.63	$9.29
1867	14.0	1.32	18.48	8.2	1.55	12.71	8.5	1.51	12.84	7.8	1.47	11.47
1868	15.6	1.00	15.60	8.5	1.38	11.73	6.6	1.40	9.24	6.1	1.47	8.97
1869	18.5	.63	11.66	11.0	.87	9.57	8.4	.91	7.64	7.8	1.28	9.98
1870	15.0	.77	11.55	10.0	.90	9.00	8.8	.87	7.66	8.4	1.15	9.66
1871	15.9	1.02	16.22	6.1	1.16	7.08	5.0	1.15	5.75	6.3	1.40	8.82
1872	11.6	1.26	14.62	12.0	1.14	13.68	9.6	1.24	11.90	9.5	1.31	12.44
1873	14.0	.92	12.88	9.0	1.11	9.99	7.2	1.22	8.78	7.3	1.57	11.46
1874	13.7	.76	10.41	10.6	.90	9.54	9.0	.96	8.64	9.0	1.32	11.88
1875	17.0	.76	12.92	10.0	.92	9.20	8.5	.88	7.48	8.5	1.07	9.10
1876	14.6	.79	11.53	10.0	.92	9.20	8.3	.85	7.06	6.5	1.13	7.34
1877	13.5	.80	10.80	12.5	.96	12.00	8.4	1.01	8.48	7.0	1.12	7.84
1878	16.3	.59	9.62	9.3	.76	7.07	5.0	.84	4.20	7.3	1.05	7.66
1879	11.0	.89	9.79	14.0	1.08	15.12	8.0	1.09	8.72	8.4	1.32	11.09
1880	10.0	.70	7.00	8.7	.93	8.09	6.0	.98	5.88	5.4	1.21	6.53
1881	9.1	1.05	9.56	7.5	1.31	9.82	6.1	1.36	8.30	6.6	1.58	10.43
1882	19.9	.67	13.33	13.4	.90	12.06	7.9	.91	7.19	6.0	1.12	6.72
1883	17.5	.78	13.65	7.7	.95	7.32	5.6	.92	5.15	5.2	1.15	5.98
1884	16.5	.45	7.42	10.6	.74	7.84	7.0	.75	5.25	6.0	1.00	6.00
1885	10.6	.65	6.89	3.6	.95	3.42	3,2	.95	3.04	5.5	1.03	5.66
1886	11.4	.58	6.61	11.2	.72	8.06	6.7	.78	5.23	6.9	1.07	7.38
1887	9.6	.61	5.86	10.2	.73	7.45	8.0	.77	6.16	6.3	.98	6.17
1888	15.2	.88	13.38	10.3	.96	9.89	8.5	.93	7.90	5.2	1.05	5.46
1889	18.4	.55	10.12	11.0	.72	7.92	7.5	.76	5.70	7.0	.98	6.86
1890	13.7	.77	10.55	9.7	.92	8.92	6.7	.97	6.50	4.5	1.09	4.90
1891	15.5	.73	11.32	12.7	.90	11.43	9.7	.93	9.02	8.0	1.10	8.80
1892	17.4	.52	9.05	11.8	.67	7.91	9.5	.68	6.46	6.7	.93	6.23
1893	8.4	.42	3.53	11.3	.57	6.44	9.2	.57	5.24	8.2	.88	7.22
1894	10.4	.44	4.58	12.5	.50	6.25	8.1	.51	4.13	8.3	.78	6.47
1895	7.7	.45	3.46	10.9	.61	6.65	8.8	.62	5.46	7.5	.80	6.00
1896	10.6	.63	6.68	8.7	.76	6.61	8.5	.74	6.29	8.0	.85	6.80
1897	15.5	.74	11.47	13.6	.89	12.10	11.2	.95	10.64	10.0	1.01	10.10
1898	14.2	.50	7.10	15.4	.62	9.55	13.2	.67	8.84	12.0	.90	10.80
1899	9.8	.52	5.10	9.1	.66	6.01	8.7	.78	6.79	7.6	.89	6.76
1900	17.7	.55	9.74	13.0	.69	8.97	9.9	.79	7.82	9.5	.89	8.46
1901	18.5	.59	10.92	12.1	.72	8.71	10.8	.74	7.99	8.7	.88	7.66
1902	10.4	.55	5.72	9.3	.74	6.88	7.2	.76	5.47	6.0	.93	5.58
1903	14.1	.59	8.32	8.4	.81	6.80	7.1	.84	5.96	9.1	.95	8.64
1904	12.4	.89	11.04	11.4	1.09	12.43	11.5	1.11	12.76	10.3	1.15	11.84
1905	13.9	.71	9.87	11.3	.87	9.83	7.2	.91	6.55	9.6	1.01	9.70
1906	15.1	.58	8.76	14.1	.73	10.29	12.5	.78	9.75	11.0	.94	10.34
1907	11.0	.82	9.02	12.0	.92	11.04	9.5	.95	9.02	10.0	1.05	10.50
1908	12.6	.88	11.09	11.6	.98	11.37	10.0	.99	9.90	11.5	1.07	12.30
1909	14.4	.96	13.82	11.8	1.11	13.10	10.4	1.15	11.96	10.5	1.30	13.65
1910	14.1	.84	11.84	12.8	.93	11.90	11.7	.98	11.47	12.0	1.13	13.56
1911	10.7	.91	9.74	12.7	.92	11.68	11.5	.96	11.04	11.5	1.20	13.80
1912	15.5	.74	11.47	10.0	.99	9.90	10.5	1.00	10.50	10.6	1.13	11,98
1913	13.0	.79	10.27	13.6	.96	13.06	12.0	.98	11.76	11.7	1.15	13.46
1914	20.5	.95	19.48	16.5	1.03	17.00	15.5	1.05	16.28	13.0	1.26	16.38
1915	12.5	.89	11.12	11.0	1.05	11.55	10.5	1.08	11.34	12.0	1.25	15.00
10-YEAR AVERAGE.												
1866–1875	15.7	.98	15.28	9.2	1.15	10.29	7.7	1.17	8.81	7.6	1.37	10.31
1876–1885	13.9	.74	9.96	9.7	.95	9.19	6.6	.97	6.33	6.4	1.17	7.52
1886–1895	12.8	.60	7.85	11.2	.73	8.09	8.3	.75	6.18	6.9	.97	6.55
1896–1905	13.7	.63	8.60	11.2	.78	8.79	9.5	.83	7.91	9.1	.95	8.63
1906–1915	13.9	.84	11.66	12.6	.96	12.09	11.4	.99	11.30	11.4	1.15	13.10

Wheat, yields per acre and prices, by States—Continued.

Year.	Mississippi.			Louisiana.			Texas.			Oklahoma.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	5.0	$1.76	$8.80	......	......	......	12.0	$1.01	$12.12	......	......	......
1867	9.5	1.72	16.34	8.0	$1.79	$14.32	9.5	1.35	12.82	......	......	......
1868	9.1	1.63	14.83	7.3	1.86	13.58	6.0	1.67	10.02	......	......	......
1869	9.0	1.39	12.51	11.5	.99	11.38	11.1	1.35	14.98	......	......	......
1870	9.7	1.36	13.19	9.7	1.36	13.19	11.7	1.55	18.14	......	......	......
1871	10.0	1.43	14.30	......	......	......	11.5	1.77	20.36	......	......	......
1872	10.3	1.39	14.32	......	......	......	18.5	1.46	27.01	......	......	......
1873	9.6	1.61	15.46	......	......	......	17.0	1.29	21.93	......	......	......
1874	9.2	1.58	14.54	......	......	......	12.5	1.22	15.25	......	......	......
1875	11.0	1.32	14.52	......	......	......	18.0	1.11	19.98	......	......	......
1876	7.7	1.26	9.70	......	......	......	13.0	.99	12.87	......	......	......
1877	8.0	1.38	11.04	......	......	......	12.0	1.18	14.16	......	......	......
1878	6.8	1.35	9.18	......	......	......	16.0	.86	13.76	......	......	......
1879	7.2	1.36	9.79	......	......	......	7.6	1.15	8.74	......	......	......
1880	6.8	1.29	8.77	......	......	......	8.0	1.05	8.40	......	......	......
1881	5.6	1.60	8.96	3.3	1.50	4.95	12.7	1.40	17.78	......	......	......
1882	4.5	1.23	5.54	3.4	1.25	4.25	9.1	.98	8.92	......	......	......
1883	5.0	1.20	6.00	......	......	......	8.5	1.00	8.50	......	......	......
1884	5.0	1.00	5.00	......	......	......	10.0	.87	8.70	......	......	......
1885	4.9	1.04	5.10	......	......	......	11.2	.80	8.96	......	......	......
1886	4.0	1.10	4.40	......	......	......	10.2	.90	9.18	......	......	......
1887	7.5	.95	7.12	......	......	......	10.0	.80	8.00	......	......	......
1888	6.3	1.05	6.62	......	......	......	10.6	1.00	10.60	......	......	......
1889	6.5	.99	6.44	......	......	......	10.3	.74	7.62	......	......	......
1890	4.7	1.10	5.17	......	......	......	7.0	.95	6.65	......	......	......
1891	7.8	1.00	7.80	......	......	......	12.0	.87	10.44	......	......	......
1892	6.8	.90	6.12	......	......	......	12.3	.75	9.22	......	......	......
1893	7.7	.85	6.54	......	......	......	10.5	.58	6.09	......	......	......
1894	9.8	.75	7.35	......	......	......	15.1	.54	8.15	11.3	$0.51	$5.76
1895	8.0	.61	4.88	......	......	......	5.7	.66	3.76	11.4	.48	5.47
1896	8.5	.82	6.97	......	......	......	11.7	.75	8.78	13.0	.68	8.84
1897	10.0	.99	9.90	......	......	......	15.8	.89	14.06	19.0	.76	14.44
1898	13.9	.83	11.54	......	......	......	14.8	.68	10.06	14.9	.52	7.75
1899	7.7	.78	6.01	......	......	......	11.1	.68	7.55	13.3	.53	7.05
1900	9.6	.84	8.06	......	......	......	18.4	.64	11.78	19.0	.53	10.07
1901	8.8	.86	7.57	......	......	......	8.9	.78	6.94	15.8	.64	10.11
1902	8.0	.85	6.80	......	......	......	9.0	.77	6.93	11.3	.59	6.67
1903	8.0	.93	7.44	......	......	......	13.4	.78	10.45	14.5	.64	9.28
1904	8.8	1.01	8.89	......	......	......	10.7	1.10	11.77	12.1	.94	11.37
1905	10.8	.95	10.26	......	......	......	8.9	.88	7.83	8.5	.70	5.95
1906	10.0	.87	8.70	......	......	......	11.5	.77	8.86	13.7	.56	7.67
1907	11.0	.88	9.68	......	......	......	7.4	.99	7.33	9.0	.83	7.47
1908	14.5	1.03	14.94	......	......	......	11.0	.98	10.78	11.6	.88	10.21
1909	11.0	1.21	13.31	......	......	......	9.1	1.18	10.74	12.8	1.01	12.93
1910	14.0	1.16	16.24	......	......	......	15.0	.98	14.70	16.3	.87	14.18
1911	12.0	1.00	12.00	......	......	......	9.4	1.00	9.40	8.0	.92	7.36
1912	12.0	.97	11.64	......	......	......	15.0	.93	13.95	12.8	.75	9.60
1913	14.0	.95	13.30	......	......	......	17.5	.94	16.45	10.0	.82	8.20
1914	13.0	1.25	16.25	......	......	......	13.0	.99	12.87	19.0	.92	17.48
1915	20.0	1.05	21.00	......	......	......	15.5	1.07	16.58	11.6	.89	10.32
10-YEAR AVERAGE.												
1866-1875	9.2	1.52	13.88	......	......	......	12.8	1.38	17.26	......	......	......
1876-1885	6.2	1.27	7.91	......	......	......	10.8	1.03	11.08	......	......	......
1886-1895	6.9	.93	6.24	......	......	......	10.4	.78	7.97	......	......	......
1896-1905	9.4	.89	8.34	......	......	......	12.3	.80	9.62	14.1	.65	9.15
1906-1915	13.2	1.04	13.71	......	......	......	12.4	.98	12.17	12.5	.84	10.54

Wheat, yields per acre and prices, by States—Continued.

Year.	Arkansas.			Montana.			Wyoming.			Colorado.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	6.5	$1.43	$9.30									
1867	9.2	1.44	13.25									
1868	13.5	1.49	20.12									
1869	11.8	1.20	14.16									
1870	10.8	1.17	12.64									
1871	8.4	1.39	11.68									
1872	10.4	1.35	14.04									
1873	10.0	1.38	13.80									
1874	10.5	1.37	14.38									
1875	12.3	.92	11.32									
1876	8.2	.87	7.13									
1877	9.0	.86	7.74									
1878	6.0	.95	5.70									
1879	8.0	1.07	8.56									
1880	7.0	1.02	7.14							17.0	$0.95	$16.15
1881	5.2	1.50	7.80							19.8	1.33	26.33
1882	7.3	.99	7.23	16.0	$1.45	$23.20	16.0	$1.20	$19.20	16.8	.94	15.79
1883	6.1	1.03	6.28	16.3	.92	15.00	15.2	.98	14.90	21.0	.96	20.16
1884	7.6	.93	7.07	18.0	.70	12.60	16.0	.73	11.68	20.0	.56	11.20
1885	6.5	1.00	6.50	20.4	.77	15.71	20.8	.80	16.64	19.8	.82	16.24
1886	7.8	.85	6.63	17.0	.75	12.75	18.9	.70	13.23	19.8	.70	13.86
1887	9.9	.82	8.12	18.0	.76	13.68				21.0	.75	15.75
1888	9.7	.95	9.22	16.5	.85	14.02				17.5	.90	15.75
1889	7.6	.85	6.46	18.1	.75	13.58				21.2	.72	15.26
1890	7.1	.98	6.96	17.0	.80	13.60				18.5	.81	14.98
1891	9.6	.90	8.64	20.0	.84	16.80	20.0	.82	16.40	20.2	.73	14.75
1892	8.2	.80	6.56	21.5	.69	14.84	17.5	.66	11.55	19.1	.58	11.08
1893	8.0	.65	5.20	21.5	.60	12.90	18.7	.65	12.16	13.2	.52	6.86
1894	8.8	.55	4.84	24.8	.54	13.39	19.6	.63	12.35	17.9	.65	11.64
1895	9.4	.59	5.55	23.9	.73	17.45	26.0	.64	16.64	23.5	.56	13.16
1896	8.0	.71	5.68	26.5	.66	17.49	24.5	.62	15.19	17.5	.61	10.68
1897	10.5	.84	8.82	32.5	.68	22.10	25.0	.70	17.50	24.0	.70	16.80
1898	11.0	.58	6.38	29.5	.58	17.11	23.7	.69	16.35	26.3	.56	14.73
1899	8.6	.64	5.50	25.7	.61	15.68	18.8	.67	12.60	23.7	.57	13.51
1900	10.1	.65	6.56	26.6	.61	16.23	17.6	.76	13.38	22.6	.59	13.33
1901	8.8	.78	6.86	26.5	.67	17.76	24.5	.69	16.90	24.1	.67	16.15
1902	9.1	.67	6.10	26.0	.62	16.12	23.5	.81	19.04	18.0	.75	13.50
1903	7.0	.78	5.46	28.2	.66	18.61	20.9	.74	15.47	26.6	.66	17.56
1904	10.1	1.01	10.20	23.9	.89	21.27	22.1	.90	19.89	22.8	.91	20.75
1905	7.9	.90	7.11	23.8	.71	16.90	25.4	.72	18.29	25.0	.70	17.50
1906	10.8	.75	8.10	24.0	.64	15.36	28.7	.73	20.95	32.5	.65	21.12
1907	9.5	.95	9.02	28.8	.81	23.33	28.5	.77	21.94	29.0	.78	22.62
1908	10.0	.95	9.50	24.2	.86	20.81	25.4	.85	21.59	21.0	.88	18.48
1909	11.4	1.10	12.54	30.8	.87	26.80	28.7	.99	28.41	29.5	.93	27.44
1910	13.9	.94	13.07	22.0	.86	18.92	25.0	.95	23.75	22.3	.82	18.29
1911	10.5	.90	9.45	28.7	.77	22.10	26.0	.94	24.44	18.9	.84	15.88
1912	10.0	.94	9.40	24.1	.64	15.42	28.7	.80	22.96	24.2	.73	17.67
1913	13.0	.90	11.70	23.8	.66	15.71	25.0	.72	18.00	21.0	.78	16.38
1914	13.0	.99	12.87	20.2	.91	18.38	22.9	.89	20.38	23.8	.87	20.71
1915	12.5	1.01	12.62	26.5	.78	20.67	26.5	.78	20.67	24.2	.80	19.36
10-YEAR AVERAGE.												
1866–1875	10.3	1.31	13.47									
1876–1885	7.1	1.02	7.12							[1] 19.1	[1] .93	[1] 17.64
1886–1895	8.6	.79	6.82	19.8	.73	14.30				19.2	.69	13.31
1896–1905	9.1	.76	6.87	26.9	.67	17.93	22.6	.73	16.46	23.1	.67	15.45
1906–1915	11.5	.94	10.83	25.3	.78	19.75	26.5	.84	22.31	24.6	.81	19.80

[1] 6-year average—1880–1885.

Wheat, yields per acre and prices, by States—Continued.

Year.	New Mexico.			Arizona.			Utah.			Nevada.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	......	......	......	......	......	......	......	......	......	......	......	......
1867	......	......	......	......	......	......	......	......	......	......	......	......
1868	......	......	......	......	......	......	......	......	......	......	......	......
1869	......	......	......	......	......	......	......	......	......	......	......	......
1870	......	......	......	......	......	......	......	......	......	23.5	$1.50	$35.25
1871	......	......	......	......	......	......	......	......	......	24.0	1.75	42.00
1872	......	......	......	......	......	......	......	......	......	25.0	1.75	43.75
1873	......	......	......	......	......	......	......	......	......	20.0	1.75	35.00
1874	......	......	......	......	......	......	......	......	......	19.0	1.75	33.25
1875	......	......	......	......	......	......	......	......	......	18.0	1.20	21.60
1876										18.2	1.10	20.02
1877	......	......	......	......	......	......	......	......	......			
1878	......	......	......	......	......	......	......	......	......	......	......	......
1879	......	......	......	......	......	......	......	......	......	......	......	......
1880	......	......	......	......	......	......	......	......	......	17.0	.95	16.15
1881	......	......	......	......	......	......	......	......	......	14.5	1.20	17.40
1882	12.0	$1.50	$18.00	14.2	$1.40	$19.88	15.3	$0.92	$14.08	21.0	1.20	25.20
1883	15.0	1.05	15.75	14.1	1.05	14.80	19.0	.92	17.48	18.3	1.10	20.13
1884	13.6	.90	12.24	13.4	.75	10.05	18.0	.82	14.76	18.9	1.00	18.90
1885	14.0	1.02	14.28	14.0	.95	13.30	19.9	.61	12.14	18.5	.92	17.02
1886	11.4	.70	7.98	13.5	.93	12.56	15.2	.62	9.42	12.9	.75	9.68
1887	15.0	.90	13.50	13.5	.82	11.07	19.0	.61	11.59	19.9	.80	15.92
1888	15.0	.95	14.25	15.0	.90	13.50	16.3	.76	12.39	16.0	.92	14.72
1889	12.7	.73	9.27	13.0	.75	9.75	15.3	.75	11.48	18.3	.75	13.72
1890	12.2	.95	11.59	12.0	.90	10.80	17.5	.78	13.65	13.5	.86	11.61
1891	11.5	.82	9.43	14.5	.75	10.88	17.5	.75	13.12	18.3	.87	15.92
1892	13.8	.80	11.04	15.6	.78	12.17	17.3	.62	10.73	19.2	.75	14.40
1893	16.8	.75	12.60	17.5	.65	11.38	13.8	.60	8.28	14.7	.73	10.73
1894	18.0	.88	15.84	17.0	1.00	17.00	22.0	.53	11.66	20.0	.75	15.00
1895	20.4	.73	14.89	20.5	.65	13.32	22.4	.44	9.86	21.7	.49	10.63
1896	21.0	.66	13.86	23.0	.80	18.40	26.5	.68	18.02	30.0	.69	20.70
1897	24.0	.75	18.00	18.0	.74	13.32	21.0	.68	14.28	24.3	.90	21.87
1898	23.8	.62	14.76	31.7	.92	29.16	28.0	.54	15.12	29.0	.95	27.55
1899	13.8	61	8.42	15.3	.64	9.79	20.7	.53	10.97	18.0	.76	13.68
1900	21.0	.68	14.28	14.6	.79	11.53	20.9	.55	11.50	24.5	.70	17.15
1901	21.5	.72	15.48	21.8	.85	18.53	20.5	.70	14.35	25.1	.88	22.09
1902	17.1	.86	14.71	18.7	1.05	19.64	21.2	.76	16.11	27.1	.98	26.56
1903	18.4	.75	13.80	25.3	.93	23.53	22.6	.80	18.08	27.6	.99	27.32
1904	12.8	1.06	13.57	25.5	1.13	28.82	26.6	.86	22.88	26.2	.92	24.10
1905	22.2	.90	19.98	22.4	1.17	26.21	26.4	.67	17.69	27.0	.77	20.79
1906	25.0	.83	20.75	25.2	1.03	25.96	27.4	.65	17.81	31.5	.85	26.78
1907	24.0	.93	22.32	25.9	1.05	27.20	28.8	.74	21.31	32.0	1.04	33.28
1908	25.0	.94	23.50	26.7	1.20	32.04	26.5	.85	22.52	30.0	1.13	33.90
1909	24.5	1.17	28.66	25.0	1.39	34.75	25.9	.90	23.31	28.7	1.04	29.85
1910	20.0	1.00	20.00	22.3	1.20	26.76	22.1	.84	18.56	26.5	1.09	28.88
1911	22.9	1.00	22.90	29.6	.95	28.12	22.3	.70	15.61	28.3	.95	26.88
1912	20.9	.90	18.81	30.7	1.10	33.77	25.7	.75	19.28	29.2	1.00	29.20
1913	18.8	.97	18.24	32.0	1.10	35.20	24.2	.73	17.67	27.7	.82	22.71
1914	24.2	.90	21.78	28.0	1.25	35.00	25.0	.86	21.50	29.6	.95	28.12
1915	22.2	.90	19.98	28.0	1.15	32.20	25.7	.86	22.10	29.6	.95	28.12
10-YEAR AVERAGE.												
1866–1875	......	......	......	......	......	......	......	......	......	[1] 21.6	[1] 1.62	[1] 35.14
1876–1885	......	......	......	......	......	......	......	......	......	[2] 18.1	[2] 1.07	[2] 19.26
1886–1895	14.7	.82	12.04	15.2	.81	12.24	17.6	.65	11.22	17.4	.77	13.23
1896–1905	19.6	.76	14.69	21.6	.90	19.89	23.4	.68	15.90	25.9	.85	22.18
1906–1915	22.8	.95	21.69	27.3	1.14	31.10	25.4	.79	19.97	29.3	.98	28.77

[1] 6-year average. [2] 7-year average.

Wheat, yields per acre and prices, by States—Continued.

Year.	Idaho.			Washington.			Oregon.			California.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	......	......	......	......	......	......	......	......	......	......	......	......
1867	......	......	......	......	......	......	......	......	......	......	......	......
1868	......	......	......	......	......	......	......	......	......	20.0	$1.03	$20.60
1869	......	......	......	......	......	......	19.0	$0.85	$16.15	18.2	.93	16.93
1870	......	......	......	......	......	......	19.5	.95	18.52	19.0	1.10	20.90
1871	......	......	......	......	......	......	19.2	1.04	19.97	11.0	1.41	15.51
1872	......	......	......	......	......	......	18.2	.74	13.47	12.2	1.11	13.54
1873	......	......	......	......	......	......	19.0	.90	17.10	13.5	1.32	17.82
1874	......	......	......	......	......	......	19.5	.68	13.26	13.2	.99	13.07
1875	......	......	......	......	......	......	17.6	.87	15.31	11.0	1.18	12.98
1876	......	......	......	......	......	......	17.0	.70	11.90	13.0	1.14	14.82
1877	......	......	......	......	......	......	20.0	1.11	22.20	9.5	1.30	12.35
1878	......	......	......	......	......	......	21.0	.92	19.32	17.0	1.03	17.51
1879	......	......	......	......	......	......	16.0	.98	15.68	14.0	1.23	17.22
1880	......	......	......	......	......	......	17.0	.78	13.26	16.0	.96	15.36
1881	......	......	......	......	......	......	17.2	.88	15.14	12.0	1.03	12.36
1882	16.0	$1.40	$22.40	16.5	$0.83	$13.70	16.7	.85	14.20	13.0	.90	11.70
1883	15.3	.90	13.77	18.7	.85	15.90	16.5	.90	14.85	13.0	1.00	13.00
1884	18.9	.72	13.61	12.6	.60	7.56	18.0	.48	8.64	13.2	.72	9.50
1885	18.5	.75	13.88	17.5	.72	12.60	15.9	.69	10.97	9.4	.67	6.30
1886	15.9	.72	11.45	17.0	.67	11.39	12.6	.68	8.57	11.6	.73	8.47
1887	17.5	.77	13.48	18.0	.67	12.06	17.5	.68	11.90	11.0	.74	8.14
1888	16.3	.87	14.18	18.5	.78	14.43	16.3	.78	12.71	12.1	.85	10.28
1889	17.8	.77	13.71	16.5	.70	11.55	16.2	.70	11.34	13.3	.70	9.31
1890	16.5	.78	12.87	18.5	.76	14.06	14.5	.75	10.88	12.0	.76	9.12
1891	20.0	.84	16.80	17.5	.75	13.12	19.0	.88	16.72	13.0	.95	12.35
1892	22.0	.60	13.20	17.2	.58	9.98	15.7	.64	10.05	13.0	.68	8.84
1893	19.3	.60	11.58	20.3	.48	9.74	17.5	.55	9.62	13.3	.53	7.05
1894	20.6	.46	9.48	16.6	.39	6.47	17.7	.43	7.61	11.3	.57	6.44
1895	17.8	.47	8.37	15.5	.41	6.36	20.0	.47	9.40	13.0	.60	7.80
1896	24.5	.65	15.92	18.0	.74	13.32	17.0	.72	12.24	14.6	.83	12.12
1897	22.0	.70	15.40	23.5	.68	15.98	17.0	.72	12.24	10.0	.83	8.30
1898	31.0	.51	15.81	24.2	.54	13.07	20.5	.62	12.71	9.1	.72	6.55
1899	24.2	.50	12.10	22.7	.51	11.58	19.2	.53	10.18	14.1	.62	8.74
1900	20.8	.46	9.57	23.5	.51	11.98	13.8	.55	7.59	10.3	.58	5.97
1901	21.2	.61	12.93	29.1	.47	13.68	21.1	.54	11.39	13.0	.60	7.80
1902	22.1	.70	15.47	22.2	.65	14.43	20.0	.67	13.40	10.9	.80	8.72
1903	21.1	.75	15.82	20.3	.69	14.01	18.2	.77	14.01	11.2	.87	9.74
1904	22.9	.80	18.32	22.2	.80	17.76	19.0	.81	15.39	10.8	.88	9.50
1905	28.2	.66	18.61	24.6	.66	16.24	18.6	.68	12.65	9.3	.82	7.63
1906	24.4	.60	14.64	20.8	.62	12.90	20.0	.66	13.20	17.1	.75	12.82
1907	25.3	.67	16.95	26.0	.75	19.50	23.4	.78	18.25	15.0	.98	14.70
1908	28.2	.74	20.87	18.8	.82	15.42	20.8	.84	17.47	14.6	1.02	14.89
1909	27.8	.87	24.19	23.2	.93	21.58	20.2	.93	18.79	14.0	1.11	15.54
1910	22.6	.72	16.27	16.9	.78	13.18	22.1	.84	18.56	18.0	.94	16.92
1911	30.7	.66	20.26	22.7	.71	16.12	21.0	.75	15.75	18.0	.88	15.84
1912	28.6	.66	18.88	23.5	.68	15.98	25.0	.72	18.00	17.0	.93	15.81
1913	27.6	.63	17.39	23.2	.73	16.94	21.0	.75	15.75	14.0	.95	13.30
1914	26.2	.87	22.79	23.5	1.00	23.50	20.8	1.02	21.22	17.0	1.04	17.68
1915	28.0	.80	22.40	25.7	.82	21.07	22.2	.84	18.65	16.0	.95	15.20
10-YEAR AVERAGE.												
1866–1875	......	......	......	......	......	......	[1] 18.9	[1] .86	[1] 16.25	[2] 14.8	[2] 1.13	[2] 16.42
1876–1885	......	......	......	......	......	......	17.5	.83	14.62	13.0	1.00	13.01
1886–1895	18.4	.69	12.51	17.6	.62	10.92	16.7	.66	10.88	12.4	.71	8.78
1896–1905	23.8	.63	15.00	23.0	.62	14.20	18.4	.66	12.18	11.3	.76	8.51
1906–1915	26.9	.72	19.46	22.4	.78	17.62	21.6	.81	17.56	16.1	.96	15.27

[1] 7-year average. [2] 8-year average.

Wheat, yields per acre and prices, by States—Continued.

Year.	The Territories.			Indian Territory.		
	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*		
1866						
1867	16.6	$1.10	$18.26			
1868						
1869	25.0	1.50	37.50			
1870	25.7	1.21	31.10			
1871	22.6	1.23	27.80			
1872	23.5	1.04	24.44			
1873	23.0	.98	22.54			
1874	19.0	1.02	19.38			
1875	19.5	1.00	19.50			
1876	18.2	1.00	18.20			
1877	18.0	1.05	18.90			
1878	12.0	.60	7.20			
1879	13.0	1.06	13.78			
1880	16.0	.90	14.40			
1881	17.9	1.08	19.33			
1882						
1883						
1884						
1885						
1886						
1887						
1888						
1889						
1890						
1891						
1892						
1893						
1894						
1895						
1896						
1897						
1898						
1899						
1900						
1901				12.2	$0.69	$8.42
1902				12.3	.61	7.50
1903				12.0	.69	8.28
1904				14.1	.98	13.82
1905				10.0	.77	7.70
1906				12.0	.62	7.44
1907						
1908						
1909						
1910						
1911						
1912						
1913						
1914						
1915						
10-YEAR AVERAGE.						
1866–1875	[1] 21.9	[1] 1.14	[1] 25.06			
1876–1885	[2] 15.8	[2] .95	[2] 15.30			
1886–1895						
1896–1905						
1906–1915						

[1] 8-year average. [2] 6-year average.

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Contribution from the Bureau of Crop Estimates.
LEON M. ESTABROOK, Chief.

Washington, D. C. ▼ February 12, 1917

CORN, YIELDS PER ACRE AND PRICES, BY STATES, 50 YEARS 1866–1915.

The year 1915 completes the first 50 years of continuous reports by the United States Department of Agriculture of the yield and value of important crops in the United States, by States. The figures relating to corn have been assembled in this circular for reference and as an historical record of one phase of American agriculture.

In the following pages the figures under yield represent bushels per acre; under price, the prevailing price paid to producers on or about December 1; and under value, the product of the given yield and price figures.

The States included in the several divisions on pages 2 and 3 are: *North Atlantic*—Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania; *North Central, East*—Ohio, Indiana, Illinois, Michigan, and Wisconsin; *North Central, West*—Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas; *South Atlantic*—Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida; *South Central*—Kentucky, Tennessee, Alabama, Mississippi, Louisiana, Texas, Oklahoma, and Arkansas; *Far West*—Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Idaho, Washington, Oregon, and California.

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Corn, yields per acre and prices, by States.

Year.	United States.			North Atlantic.			North Central, East.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bushels.	*Cents.*		*Bushels.*	*Cents.*		*Bushels.*	*Cents.*	
1866	25.3	47.4	$11.99	32.4	73.1	$23.69	34.4	33.7	$11.58
1867	23.6	57.0	13.46	32.0	91.1	29.10	26.9	52.0	13.99
1868	26.0	46.8	12.16	34.3	80.6	27.63	34.0	38.5	13.08
1869	23.6	59.8	14.08	29.8	79.8	23.79	24.9	51.5	12.82
1870	28.3	49.4	13.99	34.7	73.8	25.56	37.2	35.9	13.34
1871	29.1	43.4	12.62	34.6	72.1	24.97	37.5	33.7	12.63
1872	30.8	35.3	10.86	38.2	58.0	22.21	39.3	25.4	9.99
1873	23.8	44.2	10.51	33.7	60.4	20.38	25.4	34.6	8.78
1874	20.7	58.4	12.09	32.4	76.4	24.76	23.8	50.6	12.02
1875	29.5	36.7	10.81	37.8	58.1	21.94	33.6	33.7	11.32
1876	26.2	34.0	8.89	33.7	55.7	18.81	28.7	31.9	9.16
1877	26.7	34.8	9.28	33.4	55.1	18.41	29.7	31.8	9.44
1878	26.9	31.7	8.54	35.6	49.7	17.62	30.9	28.1	8.69
1879	29.2	37.5	10.94	34.0	58.6	19.95	34.9	34.2	11.93
1880	27.6	39.6	10.91	38.3	56.4	21.59	30.5	38.7	11.80
1881	18.6	63.6	11.82	25.7	77.0	19.81	21.9	59.0	12.92
1882	24.6	48.5	11.94	29.4	74.5	21.93	27.1	51.6	13.99
1883	22.7	42.4	9.63	26.6	69.7	18.53	25.3	42.5	10.74
1884	25.8	35.7	9.19	31.0	56.2	17.44	29.3	34.0	9.98
1885	26.5	32.8	8.69	32.1	53.6	17.18	33.3	29.7	9.87
1886	22.0	36.6	8.06	29.3	51.9	15.22	27.8	32.8	9.11
1887	20.1	44.4	8.93	32.4	54.4	17.61	21.2	43.9	9.32
1888	26.3	34.1	8.95	31.9	53.9	17.21	34.3	31.5	10.81
1889	27.0	28.3	7.63	30.1	48.2	14.53	30.2	26.7	8.07
1890	20.7	50.6	10.48	28.5	62.7	17.86	25.7	46.2	11.84
1891	27.0	40.6	10.98	33.4	62.4	20.83	32.4	39.0	12.66
1892	23.1	39.4	9.09	31.7	58.4	18.51	27.6	39.4	10.86
1893	22.5	36.5	8.21	26.3	52.1	13.71	25.2	35.0	8.83
1894	19.4	45.7	8.86	31.6	57.3	18.08	27.5	40.1	11.03
1895	26.2	25.3	6.64	34.6	41.9	14.48	34.8	24.2	8.43
1896	28.2	21.5	6.06	37.8	35.2	13.31	38.9	19.4	7.56
1897	23.8	26.3	6.26	34.1	36.7	12.50	31.9	22.4	7.14
1898	24.8	28.7	7.10	36.3	41.4	15.03	33.3	26.2	8.74
1899	25.3	30.3	7.66	33.0	42.5	14.02	35.7	27.7	9.89
1900	25.3	35.7	9.02	28.6	46.5	13.28	37.4	32.7	12.25
1901	16.7	60.5	10.09	35.0	65.9	23.10	23.1	55.7	12.86
1902	26.8	40.3	10.81	32.5	60.4	19.62	36.8	38.5	14.19
1903	25.5	42.5	10.82	28.3	58.2	16.49	31.9	38.9	12.41
1904	26.8	44.1	11.79	32.9	61.2	20.15	33.7	41.7	14.04
1905	28.8	41.2	11.88	36.7	56.9	20.85	39.2	39.4	15.45
1906	30.3	39.9	12.06	38.3	54.4	20.81	38.4	37.5	14.38
1907	25.9	51.6	13.38	31.3	66.4	20.74	35.0	47.1	16.46
1908	26.2	60.6	15.88	39.3	74.9	29.40	32.7	59.7	19.50
1909	26.1	58.6	15.32	33.4	71.7	23.97	37.2	53.4	19.87
1910	27.7	48.0	13.31	40.3	60.9	24.56	37.7	41.6	15.70
1911	23.9	61.8	14.79	42.4	71.4	30.27	34.9	56.5	19.69
1912	29.2	48.7	14.20	41.4	66.1	27.34	39.8	43.6	17.36
1913	23.1	69.1	15.99	36.8	74.9	27.54	32.2	62.3	20.09
1914	25.8	64.4	16.65	42.0	76.6	32.20	33.0	61.2	20.18
1915	28.2	57.5	16.22	39.5	73.7	29.12	36.0	55.3	19.93
10-YEAR AVERAGE.									
1866–1875	26.1	47.8	12.26	34.0	72.3	24.40	31.7	39.0	11.96
1876–1885	25.5	40.1	9.98	32.0	60.6	19.13	29.2	38.2	10.85
1886–1895	23.4	38.2	8.78	31.0	54.3	16.80	28.7	35.9	10.10
1896–1905	25.2	37.1	9.15	33.5	50.5	16.84	34.2	34.3	11.45
1906–1915	26.6	56.0	14.78	38.5	69.1	26.60	35.7	51.8	18.32

Corn, yields per acre and prices, by States—Continued.

Year.	North Central, West.			South Atlantic.			South Central.			Far West.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.	*Cents.*		*Bush.*	*Cents.*		*Bush.*	*Cents.*		*Bush.*	*Cents.*	
1866	31.3	36.0	$11.25	11.9	75.1	$8.92	20.3	60.3	$12.27	......	......	......
1867	30.8	44.4	13.67	14.9	71.1	10.63	21.2	52.7	11.18	29.4	90.0	$26.46
1868	31.9	37.6	11.98	15.6	63.8	9.93	21.6	45.7	9.86	45.0	100.0	45.00
1869	33.5	42.2	14.13	14.2	81.6	11.56	21.3	69.6	14.83	32.3	100.8	32.53
1870	31.4	36.6	11.47	15.3	72.6	11.08	24.0	66.2	15.87	35.5	108.6	38.57
1871	40.2	24.8	9.95	14.9	68.1	10.18	20.6	62.7	12.91	32.8	104.8	34.39
1872	38.2	22.0	8.43	15.9	62.0	9.84	23.5	49.1	11.52	34.0	93.3	31.68
1873	28.7	30.7	8.79	15.0	64.7	9.69	21.0	60.3	12.66	34.1	83.3	28.40
1874	21.1	50.1	10.55	15.1	70.2	10.58	17.2	67.8	11.67	32.0	98.9	31.68
1875	36.6	23.0	8.40	15.8	58.6	9.23	22.6	49.2	11.09	30.2	104.1	31.40
1876	31.4	23.9	7.51	15.0	50.4	7.58	22.4	37.6	8.42	28.5	100.6	28.71
1877	32.7	23.6	7.73	14.6	55.6	8.10	21.6	43.4	9.37	26.9	80.9	21.75
1878	34.0	19.3	6.56	14.0	49.3	6.93	19.6	47.5	9.29	32.4	60.8	19.72
1879	36.9	24.5	9.07	14.4	58.4	8.40	19.9	55.5	11.01	29.0	84.7	24.57
1880	32.6	29.4	9.56	17.3	53.0	9.16	22.2	47.1	10.45	29.9	73.6	21.99
1881	21.7	50.9	11.07	12.3	79.1	9.71	13.0	84.9	11.05	30.1	90.1	27.09
1882	29.9	37.7	11.26	15.9	58.9	9.35	20.4	51.6	10.51	24.9	91.2	22.68
1883	29.3	30.2	8.83	12.3	61.9	7.60	17.8	52.1	9.26	23.1	84.4	19.49
1884	34.9	23.2	8.10	13.1	60.5	7.95	17.4	52.8	9.19	27.4	62.4	17.10
1885	32.5	23.7	7.69	12.9	51.3	6.61	19.8	44.1	8.72	25.2	69.3	17.46
1886	24.0	28.2	6.77	12.9	52.2	6.72	18.2	46.5	8.47	25.9	62.2	16.08
1887	22.3	35.0	7.79	14.3	55.1	7.89	18.0	51.5	9.29	27.2	63.4	17.24
1888	31.9	25.9	8.27	12.9	53.6	6.91	19.1	43.2	8.24	23.6	67.3	15.91
1889	35.4	19.7	6.97	13.6	49.3	6.73	19.4	39.7	7.70	24.9	58.1	14.46
1890	23.1	43.9	10.16	13.8	59.6	8.24	16.4	61.0	10.00	23.9	66.4	15.85
1891	32.1	32.0	10.29	15.8	59.2	9.33	20.4	48.9	9.99	27.6	68.3	18.85
1892	27.0	32.0	8.64	12.8	53.9	6.89	18.4	45.2	8.31	23.7	50.5	11.99
1893	27.2	28.6	7.77	13.6	51.5	7.03	17.5	48.0	8.38	22.4	53.6	12.01
1894	15.1	42.7	6.44	14.3	53.5	7.67	19.1	48.3	9.20	20.2	61.8	12.48
1895	27.2	18.9	5.14	15.4	39.8	6.12	23.0	31.1	7.13	24.6	47.9	11.76
1896	32.7	15.9	5.19	15.2	37.0	5.63	16.6	33.9	5.64	20.9	45.7	9.52
1897	25.4	19.7	5.01	14.6	41.4	6.05	17.8	39.8	7.09	22.5	46.9	10.56
1898	24.5	24.2	5.92	15.2	40.4	6.13	22.6	32.6	7.39	19.9	48.4	9.64
1899	28.1	24.9	7.00	14.4	44.3	6.37	17.9	39.2	7.01	19.8	50.9	10.06
1900	27.7	29.9	8.29	12.9	53.0	6.83	17.9	46.5	8.31	20.8	53.9	11.21
1901	15.6	54.7	8.53	14.2	69.6	9.85	11.9	72.5	8.63	23.1	72.2	16.68
1902	32.0	33.0	10.54	14.7	60.1	8.86	16.8	49.9	8.38	21.6	69.7	15.04
1903	27.9	34.5	9.63	15.3	61.4	9.39	22.4	50.0	11.20	23.8	65.6	15.59
1904	28.7	36.2	10.39	16.5	63.3	10.44	23.1	50.2	11.61	24.1	66.4	16.01
1905	32.4	33.7	10.91	16.0	60.6	9.69	21.8	48.2	10.51	26.3	62.2	16.37
1906	34.1	32.5	11.08	16.9	61.1	10.30	24.8	46.3	11.47	29.6	61.0	18.06
1907	26.8	44.3	11.89	17.8	70.6	12.54	21.5	58.8	12.61	27.5	73.4	20.21
1908	27.4	53.4	14.65	18.3	77.1	14.13	22.7	63.3	14.34	25.3	79.2	20.07
1909	26.7	52.1	13.91	18.7	79.8	14.90	18.7	68.1	12.72	27.3	79.0	21.57
1910	28.5	40.1	11.43	19.6	72.3	14.21	21.5	58.3	12.55	23.0	72.3	16.62
1911	23.9	56.3	13.44	20.0	78.8	15.76	16.1	69.7	11.20	19.9	82.1	16.34
1912	31.5	38.6	12.17	19.5	76.0	14.83	21.4	60.8	13.01	23.7	63.3	14.97
1913	20.7	62.3	12.88	20.5	84.2	17.29	19.3	79.1	15.30	19.8	77.2	15.29
1914	27.8	55.9	15.80	19.6	82.9	16.24	19.2	71.5	13.71	25.9	70.4	18.25
1915	29.1	51.9	15.12	20.7	75.0	15.55	23.8	58.4	13.89	27.0	67.1	18.10
10-YEAR AVERAGE.												
1866–1875	32.4	34.7	10.86	14.7	68.8	10.16	21.3	58.4	12.39	30.5	88.4	30.01
1876–1885	31.6	28.6	8.74	14.2	57.8	8.14	19.4	51.7	9.73	27.7	79.8	22.06
1886–1895	26.5	30.7	7.82	13.9	52.8	7.35	19.0	46.3	8.67	24.4	60.0	14.66
1896–1905	27.5	30.7	8.14	14.9	53.1	7.92	18.9	46.3	8.58	22.3	58.2	13.07
1906–1915	27.6	48.7	13.24	19.2	75.8	14.58	20.9	63.4	13.08	24.9	72.5	17.95

Corn, yields per acre and prices, by States—Continued.

Year.	Maine.			New Hampshire.			Vermont.			Massachusetts.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	33.0	$0.94	$31.02	32.0	$0.95	$30.40	33.3	$0.98	$32.63	34.0	$0.93	$31.62
1867	33.4	1.14	38.08	35.5	1.12	39.76	36.2	1.09	39.46	35.7	1.10	39.27
1868	29.8	1.03	30.69	35.0	1.06	37.10	38.5	1.00	38.50	37.0	.98	36.26
1869	24.3	1.01	24.54	30.0	1.03	30.90	34.0	1.11	37.74	34.2	1.05	35.91
1870	33.0	1.02	33.66	36.5	.98	35.77	39.6	.99	39.20	33.0	.88	29.04
1871	27.2	.88	23.94	35.7	.85	30.34	35.6	.89	31.68	34.3	.88	30.18
1872	33.5	.83	27.80	38.2	.84	32.09	39.0	.74	28.86	34.0	.80	27.20
1873	24.0	.84	20.16	37.5	.85	31.88	31.0	.78	24.18	35.0	.77	26.95
1874	24.6	1.02	25.09	36.4	1.01	36.76	36.1	.99	35.74	32.0	.99	31.68
1875	30.5	.84	25.62	38.0	.82	31.16	37.0	.82	30.34	37.0	.83	30.71
1876	31.0	.72	22.32	42.0	.72	30.24	39.0	.71	27.69	35.0	.69	24.15
1877	36.0	.76	27.36	42.5	.77	32.72	39.0	.75	29.25	34.7	.68	23.60
1878	40.0	.65	26.00	39.0	.61	23.79	41.0	.58	23.78	36.0	.62	22.32
1879	30.0	.76	22.80	32.5	.78	25.35	36.0	.73	26.28	36.0	.78	28.08
1880	35.4	.77	27.26	38.0	.73	27.74	32.0	.71	22.72	33.5	.75	25.12
1881	34.0	.91	30.94	34.2	.87	29.75	35.7	.86	30.70	25.1	.88	22.09
1882	29.2	.92	26.86	23.4	.96	22.46	33.9	.94	31.87	21.7	.95	20.62
1883	35.0	.82	28.70	36.0	.82	29.52	31.0	.79	24.49	35.0	.80	28.00
1884	34.7	.75	26.02	33.2	.76	25.23	33.2	.65	21.58	34.0	.72	24.48
1885	32.3	.70	22.61	33.8	.71	24.00	32.2	.64	20.61	34.0	.70	23.80
1886	31.4	.67	21.04	35.4	.68	24.07	32.8	.66	21.65	32.7	.66	21.58
1887	35.2	.68	23.94	34.3	.69	23.67	35.5	.68	24.14	35.4	.70	24.78
1888	19.3	.75	14.48	22.6	.72	16.27	24.3	.66	16.04	30.1	.68	20.47
1889	36.0	.57	20.52	36.5	.56	20.44	35.0	.55	19.25	34.3	.54	18.52
1890	36.2	.74	26.79	36.5	.72	26.28	33.5	.72	24.12	34.5	.70	24.15
1891	37.5	.80	30.00	35.8	.77	27.57	37.2	.76	28.27	39.5	.78	30.81
1892	35.5	.67	23.78	37.8	.65	24.57	38.0	.64	24.32	38.7	.62	23.99
1893	30.3	.62	18.79	31.7	.57	18.07	32.4	.61	19.76	33.5	.62	20.77
1894	39.9	.72	28.73	34.3	.76	26.07	40.8	.69	28.15	34.5	.61	21.04
1895	42.0	.54	22.68	40.2	.51	20.50	45.6	.48	21.89	43.9	.52	22.83
1896	37.0	.47	17.39	42.0	.45	18.90	41.0	.38	15.58	43.0	.46	19.78
1897	37.0	.47	17.39	34.0	.45	15.30	35.0	.43	15.05	32.5	.47	15.28
1898	40.0	.48	19.20	41.0	.46	18.86	43.0	.44	18.92	40.0	.49	19.60
1899	36.0	.50	18.00	39.0	.49	19.11	36.0	.47	16.92	36.0	.51	18.36
1900	36.0	.55	19.80	37.0	.56	20.72	40.0	.50	20.00	38.0	.54	20.52
1901	39.4	.76	29.94	38.5	.78	30.03	40.0	.73	29.20	40.5	.76	30.78
1902	21.7	.74	16.06	23.3	.73	17.01	21.8	.68	14.82	31.3	.74	23.16
1903	30.2	.66	19.93	21.0	.63	13.23	23.4	.62	14.51	24.0	.66	15.84
1904	39.7	.81	32.16	27.3	.72	19.66	35.9	.73	26.21	36.0	.72	25.92
1905	34.3	.69	23.67	37.0	.69	25.53	34.7	.68	23.60	37.5	.70	26.25
1906	37.0	.64	23.68	37.5	.64	24.00	35.5	.59	20.94	39.7	.60	23.82
1907	37.0	.75	27.75	35.0	.75	26.25	36.0	.75	27.00	36.0	.75	27.00
1908	40.5	.84	34.02	39.0	.79	30.81	40.3	.78	31.43	40.4	.81	32.72
1909	38.0	.80	30.40	35.1	.76	26.68	37.0	.73	27.01	38.0	.81	30.78
1910	46.0	.71	32.66	46.0	.69	31.74	43.0	.66	28.38	45.5	.70	31.85
1911	44.0	.90	39.60	45.0	.82	36.90	41.0	.80	32.80	44.0	.83	36.52
1912	40.0	.75	30.00	46.0	.75	34.50	40.0	.72	28.80	45.0	.77	34.65
1913	38.0	.87	33.06	37.0	.81	29.97	37.0	.81	29.97	40.5	.85	34.42
1914	46.0	.88	40.48	46.0	.82	37.72	47.0	.81	38.07	47.0	.85	39.95
1915	41.0	.85	34.85	45.0	.76	34.20	46.0	.84	38.64	47.0	.80	37.60
10-YEAR AVERAGE.												
1866–1875	29.3	.96	28.06	35.5	.95	33.62	36.0	.94	33.83	34.6	.92	31.88
1876–1885	33.8	.78	26.09	35.5	.77	27.08	35.3	.74	25.90	32.5	.76	24.23
1886–1895	34.3	.68	23.08	34.5	.66	22.75	35.5	.64	22.76	35.7	.64	22.89
1896–1905	35.1	.61	21.35	34.0	.60	19.84	35.1	.57	19.48	35.9	.60	21.55
1906–1915	40.8	.80	32.65	41.2	.76	31.28	40.3	.75	30.30	42.3	.78	32 93

Corn, yields per acre and prices, by States—Continued.

Year	Rhode Island.			Connecticut.			New York.			New Jersey.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	27.3	$0.99	$27.03	33.0	$0.88	$29.04	27.0	$0.81	$21.87	43.3	$0.72	$31.18
1867	25.7	1.17	30.07	33.0	1.07	35.31	30.4	.95	28.88	33.1	.88	29.13
1868	27.0	1.23	33.21	34.0	1.00	34.00	32.0	.83	26.56	37.5	.74	27.75
1869	25.2	1.01	25.45	31.2	1.03	32.14	27.1	.82	22.22	30.8	.75	23.10
1870	26.0	.95	24.70	26.4	1.02	26.93	34.0	.78	26.52	33.0	.73	24.09
1871	27.3	.89	24.30	31.4	.96	30.14	33.0	.74	24.42	36.0	.67	24.12
1872	30.0	.80	24.00	31.2	.81	25.27	37.5	.62	23.25	39.5	.55	21.72
1873	28.7	.85	24.40	30.0	.87	26.10	31.0	.64	19.84	36.0	.57	20.52
1874	24.3	1.06	25.76	30.0	1.06	31.80	30.0	.84	25.20	35.0	.74	25.90
1875	27.5	.96	26.40	29.0	.87	25.23	34.0	.65	22.10	41.0	.57	23.37
1876	35.0	.69	24.15	32.5	.68	22.10	30.0	.62	18.60	36.0	.51	18.36
1877	33.0	.82	27.06	29.0	.78	22.62	32.0	.58	18.56	36.4	.51	18.56
1878	32.0	.53	16.96	29.6	.62	18.35	36.0	.50	18.00	36.0	.45	16.20
1879	32.0	.75	24.00	29.0	.74	21.46	33.0	.61	20.13	34.0	.58	19.72
1880	30.0	.90	27.00	29.0	.75	21.75	34.8	.57	19.84	41.0	.58	23.78
1881	27.0	.90	24.30	25.5	.80	20.40	26.4	.77	20.33	23.2	.77	17.86
1882	23.0	.92	21.16	20.1	.96	19.30	27.5	.77	21.18	28.9	.76	21.96
1883	32.0	.85	27.20	30.0	.81	24.30	23.0	.73	16.79	28.0	.65	18.20
1884	30.4	.78	23.71	31.0	.65	20.15	30.1	.60	18.06	32.0	.54	17.28
1885	33.5	.72	24.12	35.0	.63	22.05	30.7	.58	17.81	32.0	.53	16.96
1886	31.5	.67	21.10	34.3	.63	21.61	31.3	.56	17.53	27.2	.50	13.60
1887	32.0	.70	22.40	34.0	.67	22.78	33.0	.57	18.81	30.0	.55	16.50
1888	30.4	.70	21.28	31.2	.65	20.28	32.4	.58	18.79	32.4	.53	17.17
1889	31.3	.56	17.53	31.0	.54	16.74	29.3	.49	14.36	30.2	.50	15.10
1890	32.7	.72	23.54	35.7	.70	24.99	26.6	.65	17.29	31.3	.62	19.41
1891	34.5	.79	27.26	36.0	.76	27.36	31.8	.66	20.99	34.2	.65	22.23
1892	33.4	.63	21.04	34.5	.62	21.39	33.0	.60	19.80	31.6	.58	18.33
1893	24.4	.69	16.84	28.2	.64	18.05	29.5	.55	16.22	25.9	.52	13.47
1894	31.4	.75	23.55	31.0	.68	21.08	28.2	.61	17.20	33.1	.54	17.87
1895	30.9	.56	17.30	37.9	.51	19.33	35.6	.45	16.02	33.0	.42	13.86
1896	34.0	.49	16.66	38.0	.42	15.96	34.0	.38	12.92	33.0	.36	11.88
1897	31.0	.54	16.74	31.5	.49	15.44	31.0	.40	12.40	31.5	.38	11.97
1898	34.0	.64	21.76	37.0	.52	19.24	33.0	.43	14.19	37.0	.40	14.80
1899	31.0	.53	16.43	39.0	.50	19.50	31.0	.45	13.95	39.0	.40	15.60
1900	32.0	.67	21.44	38.0	.55	20.90	32.0	.47	15.04	33.0	.45	14.85
1901	32.1	.76	24.40	39.0	.75	29.25	33.0	.72	23.76	36.9	.66	24.35
1902	28.4	.78	22.15	31.5	.74	23.31	25.0	.67	16.75	34.5	.56	19.32
1903	30.1	.81	24.38	22.4	.67	15.01	25.0	.60	15.00	24.0	.57	13.68
1904	34.1	.84	28.64	38.9	.73	28.40	27.3	.64	17.47	38.0	.58	22.04
1905	32.5	.71	23.08	42.7	.71	30.32	31.5	.61	19.22	35.8	.55	19.69
1906	33.1	.64	21.18	40.0	.60	24.00	34.9	.59	20.59	36.3	.53	19.24
1907	31.2	.80	24.96	33.0	.75	24.75	27.0	.71	19.17	31.5	.63	19.84
1908	42.8	.90	38.52	41.3	.80	33.04	38.8	.80	31.04	38.0	.69	26.22
1909	33.2	.97	32.20	41.0	.75	30.75	36.0	.74	26.64	32.7	.71	23.22
1910	40.0	.83	33.20	53.2	.68	36.18	38.3	.63	24.13	36.0	.60	21.60
1911	45.0	.95	42.75	48.5	.83	40.26	38.5	.77	29.64	36.8	.71	26.13
1912	41.5	.88	36.52	50.0	.77	38.50	38.6	.70	27.02	38.0	.68	25.84
1913	36.5	.99	36.14	38.5	.85	32.72	28.5	.81	23.08	39.5	.75	29.62
1914	42.0	.98	41.16	46.0	.89	40.94	41.0	.83	34.03	38.5	.76	29.26
1915	43.0	1.00	43.00	50.0	.85	42.50	40.0	.78	31.20	38.0	.75	28.50
10-YEAR AVERAGE.												
1866–1875	26.9	.99	26.53	30.9	.96	29.60	31.6	.77	24.09	36.5	.69	25.09
1876–1885	30.8	.79	23.97	29.1	.74	21.25	30.4	.63	18.93	32.8	.59	18.89
1886–1895	31.2	.68	21.18	33.4	.64	21.36	31.1	.57	17.70	30.9	.54	16.75
1896–1905	31.9	.68	21.57	35.8	.61	21.73	30.3	.54	16.07	34.3	.49	16.82
1906–1915	38.8	.89	34.96	44.2	.78	34.36	36.2	.74	26.65	36.5	.68	24.95

Corn, yields per acre and prices, by States—Continued.

Year.	Pennsylvania.			Delaware.			Maryland.			Virginia.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	34.4	$0.63	$21.67	16.0	$0.61	$9.76	30.0	$0.65	$19.50	20.0	$0.51	$10.20
1867	32.0	.84	26.88	16.3	.73	11.90	28.4	.78	22.15	20.9	.61	12.75
1868	35.0	.74	25.90	25.0	.63	15.75	27.7	.65	18.00	19.3	.57	11.00
1869	31.4	.73	22.92	18.0	.55	9.90	20.2	.58	11.72	15.5	.72	11.16
1870	35.8	.67	23.99	25.0	.58	14.50	22.5	.64	14.40	20.0	.58	11.60
1871	35.5	.69	24.50	22.0	.54	11.88	23.6	.58	13.69	22.6	.60	13.56
1872	39.0	.53	20.67	20.0	.49	9.80	23.0	.50	11.50	21.0	.51	10.71
1873	35.1	.55	19.30	19.0	.49	9.31	21.4	.63	13.48	19.0	.54	10.26
1874	33.2	.69	22.91	18.0	.63	11.34	20.5	.66	13.53	20.0	.58	11.60
1875	40.0	.51	20.40	26.0	.50	13.00	30.0	.48	14.40	22.0	.47	10.34
1876	35.0	.50	17.50	30.0	.46	13.80	29.0	.45	13.05	20.0	.42	8.40
1877	33.0	.50	16.50	22.0	.49	10.78	28.0	.52	14.56	19.6	.45	8.82
1878	35.0	.48	16.80	25.0	.39	9.75	23.5	.45	10.58	17.5	.43	7.52
1879	35.0	.54	18.90	27.0	.55	14.85	30.6	.52	15.91	19.0	.49	9.31
1880	40.6	.53	21.52	32.0	.50	16.00	32.0	.49	15.68	25.0	.42	10.50
1881	25.2	.75	18.90	14.4	.60	8.64	24.2	.64	15.49	15.0	.71	10.65
1882	31.3	.70	21.91	18.9	.59	11.15	25.9	.58	15.02	19.1	.53	10.12
1883	27.0	.67	18.09	18.0	.50	9.00	23.5	.51	11.98	14.0	.60	8.40
1884	31.0	.52	16.12	18.5	.43	7.96	21.8	.48	10.46	15.2	.56	8.51
1885	32.5	.49	15.92	19.3	.40	7.72	22.0	.46	10.12	14.9	.47	7.00
1886	28.2	.47	13.25	16.6	.42	6.97	20.9	.43	8.99	15.5	.45	6.98
1887	32.2	.50	16.10	20.0	.43	8.60	27.0	.45	12.15	17.5	.47	8.22
1888	32.5	.50	16.25	17.4	.44	7.66	23.7	.45	10.66	16.3	.49	7.99
1889	29.8	.46	13.71	17.5	.42	7.35	20.6	.43	8.86	15.9	.44	7.00
1890	27.5	.60	16.50	18.5	.50	9.25	22.5	.50	11.25	17.5	.55	9.62
1891	33.3	.57	18.98	22.0	.55	12.10	25.5	.53	13.52	19.7	.50	9.85
1892	30.5	.57	17.38	18.7	.44	8.23	20.6	.45	9.27	15.3	.53	8.11
1893	24.5	.49	12.00	24.6	.40	9.84	24.2	.44	10.65	18.9	.46	8.69
1894	32.0	.55	17.60	22.0	.45	9.90	22.9	.50	11.45	19.1	.47	8.98
1895	33.5	.39	13.06	21.0	.34	7.14	26.8	.37	9.92	18.6	.37	6.88
1896	40.0	.33	13.20	22.0	.25	5.50	32.0	.32	10.24	21.5	.32	6.88
1897	36.0	.34	12.24	29.0	.30	8.70	33.0	.30	9.90	18.0	.38	6.84
1898	37.0	.40	14.80	25.0	.31	7.75	31.0	.35	10.85	22.0	.35	7.70
1899	32.0	.41	13.12	22.0	.34	7.48	32.0	.36	11.52	20.0	.38	7.60
1900	25.0	.45	11.25	24.0	.38	9.12	26.0	.41	10.66	16.0	.49	7.84
1901	35.0	.62	21.70	30.0	.57	17.10	34.2	.58	19.84	22.2	.59	13.10
1902	36.1	.58	20.94	28.0	.49	13.72	32.4	.51	16.52	22.0	.52	11.44
1903	31.2	.57	17.78	27.5	.49	13.48	28.7	.51	14.64	21.8	.53	11.55
1904	34.0	.59	20.06	30.4	.49	14.90	33.4	.50	16.70	23.3	.59	13.75
1905	38.9	.54	21.01	30.4	.47	14.29	36.9	.48	17.71	23.4	.53	12.40
1906	40.2	.52	20.90	30.0	.42	12.60	35.0	.45	15.75	24.3	.55	13.36
1907	32.5	.64	20.80	27.5	.52	14.30	34.2	.54	18.47	25.0	.64	16.00
1908	39.5	.73	28.84	32.0	.59	18.88	36.6	.62	22.69	26.0	.71	18.46
1909	32.0	.70	22.40	31.0	.58	17.98	31.4	.65	20.41	23.2	.74	17.17
1910	41.0	.59	24.19	31.8	.52	16.54	33.5	.58	19.43	25.5	.65	16.58
1911	44.5	.68	30.26	34.0	.61	20.74	36.5	.63	23.00	24.0	.73	17.52
1912	42.5	.63	26.78	34.0	.51	17.34	36.5	.55	20.08	24.0	.71	17.04
1913	39.0	.72	28.08	31.5	.59	18.58	33.0	.65	21.45	26.0	.76	19.76
1914	42.5	.73	31.02	36.0	.62	22.32	37.0	.68	25.16	20.5	.81	16.60
1915	38.5	.70	26.95	31.5	.62	19.53	35.0	.61	21.35	28.5	.71	20.24
10-YEAR AVERAGE.												
1866–1875	35.1	.66	22.91	20.5	.58	11.71	24.7	.62	15.24	20.0	.57	11.32
1876–1885	32.6	.57	18.22	22.5	.49	10.96	26.0	.51	13.28	17.9	.51	8.92
1886–1895	30.4	.51	15.48	19.8	.44	8.70	23.5	.46	10.67	17.4	.47	8.23
1896–1905	34.5	.48	16.61	26.8	.41	11.20	32.0	.43	13.86	21.0	.47	9.91
1906–1915	39.2	.66	26.02	31.9	.56	17.88	34.9	.60	20.78	24.7	.70	17.27

Corn, yields per acre and prices, by States—Continued.

Year.	West Virginia.			North Carolina.			South Carolina.			Georgia.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	......	......	......	12.0	$0.78	$9.36	5.9	$1.10	$6.49	6.2	$1.06	$6.57
1867	29.7	$0.64	$19.01	11.6	.74	8.58	9.6	.82	7.87	13.1	.69	9.04
1868	35.0	.56	19.60	14.3	.58	8.29	10.2	.74	7.55	12.7	.68	8.64
1869	27.8	.63	17.51	14.8	.79	11.69	11.6	1.11	12.88	11.0	.96	10.56
1870	30.4	.57	17.33	14.6	.70	10.22	8.9	.95	8.46	13.5	.81	10.94
1871	27.6	.57	15.73	14.0	.64	8.96	10.0	.83	8.30	10.3	.84	8.65
1872	28.5	.49	13.96	16.0	.55	8.80	10.5	.85	8.92	12.5	.76	9.50
1873	29.0	.50	14.50	14.2	.59	8.38	9.5	.87	8.26	12.3	.76	9.35
1874	26.5	.55	14.58	16.4	.65	10.66	11.0	.90	9.90	11.1	.83	9.21
1875	29.1	.49	14.26	15.0	.52	7.80	10.2	.87	8.87	10.0	.75	7.50
1876	28.2	.41	11.56	14.6	.49	7.15	8.2	.71	5.82	11.0	.55	6.05
1877	25.5	.46	11.73	14.0	.51	7.14	9.0	.76	6.84	10.5	.66	6.93
1878	27.2	.42	11.42	13.6	.45	6.12	9.3	.54	5.02	11.0	.61	6.71
1879	31.0	.46	14.26	15.0	.58	8.70	7.5	.75	5.62	9.3	.70	6.51
1880	30.0	.47	14.10	16.4	.52	8.53	9.3	.77	7.16	9.2	.69	6.35
1881	22.7	.74	16.80	11.7	.79	9.24	6.7	.99	6.63	8.3	.97	8.05
1882	25.4	.58	14.73	14.0	.53	7.42	12.0	.68	8.16	13.3	.65	8.64
1883	24.3	.53	12.88	11.5	.65	7.48	8.0	.73	5.84	8.7	.67	5.83
1884	20.0	.56	11.20	12.5	.60	7.50	9.2	.68	6.26	10.8	.70	7.56
1885	23.8	.40	9.52	9.9	.55	5.44	9.0	.56	5.04	11.3	.58	6.55
1866	22.8	.42	9.58	10.5	.57	5.98	9.1	.60	5.46	10.8	.60	6.48
1887	19.0	.54	10.26	13.4	.59	7.91	10.0	.62	6.20	11.0	.63	6.93
1888	23.8	.48	11.42	10.6	.58	6.15	8.7	.60	5.22	9.6	.60	5.76
1889	22.4	.40	8.96	12.0	.53	6.36	11.5	.54	6.21	11.2	.55	6.16
1890	20.0	.60	12.00	13.3	.55	7.32	10.2	.70	7.14	10.5	.69	7.24
1891	27.3	.52	14.20	14.1	.58	8.18	11.6	.70	8.12	12.2	.69	8.42
1892	22.5	.56	12.60	10.2	.54	5.51	10.5	.57	5.98	11.2	.56	6.27
1893	21.7	.55	11.94	12.3	.50	6.15	7.7	.60	4.62	11.1	.56	6.22
1894	18.5	.57	10.54	13.4	.47	6.30	11.2	.65	7.28	11.7	.58	6.79
1895	24.2	.40	9.68	14.5	.38	5.51	11.1	.46	5.11	13.0	.41	5.33
1896	30.0	.34	10.20	12.0	.37	4.44	9.0	.46	4.14	11.0	.43	4.73
1897	24.5	.40	9.80	13.0	.43	5.59	9.0	.49	4.41	11.0	.48	5.28
1898	29.0	.37	10.73	14.0	.43	6.02	10.0	.46	4.60	9.0	.48	4.32
1899	26.0	.45	11.70	13.0	.47	6.11	9.0	.50	4.50	10.0	.50	5.00
1900	27.0	.50	13.50	12.0	.57	6.84	7.0	.64	4.48	10.0	.57	5.70
1901	23.0	.65	14.95	12.0	.73	8.76	6.9	.84	5.80	10.0	.82	8.20
1902	26.5	.54	14.31	13.9	.60	8.34	10.4	.69	7.18	9.0	.73	6.57
1903	22.6	.64	14.46	14.7	.61	8.97	10.3	.69	7.11	11.7	.69	8.07
1904	25.3	.64	16.19	15.2	.62	9.42	12.4	.70	8.68	11.9	.71	8.45
1905	29.8	.53	15.79	13.9	.64	8.90	10.9	.74	8.07	11.0	.70	7.70
1906	30.3	.55	16.66	15.3	.68	10.40	12.2	.73	8.91	12.0	.67	8.04
1907	28.0	.72	20.16	16.5	.74	12.21	15.1	.78	11.78	13.0	.76	9.88
1908	31.2	.77	24.02	18.0	.79	14.22	14.1	.91	12.83	12.5	.82	10.25
1909	31.4	.74	23.24	16.8	.85	14.28	16.7	.90	15.03	13.9	.86	11.95
1910	26.0	.68	17.68	18.6	.76	14.14	18.5	.82	15.17	14.5	.78	11.31
1911	25.7	.77	19.79	18.4	.82	15.09	18.2	.91	16.56	16.0	.83	13.28
1912	33.8	.65	21.97	18.2	.83	15.11	17.9	.85	15.22	13.8	.85	11.73
1913	31.0	.80	24.80	19.5	.88	17.16	19.5	.97	18.92	15.5	.91	14.10
1914	31.0	.83	25.73	20.3	.86	17.46	18.5	.92	17.02	14.0	.85	11.90
1915	31.5	.74	23.31	21.0	.77	16.17	16.5	.87	14.36	15.0	.78	11.70
10-YEAR AVERAGE.												
1866–1875	[1] 29.3	[1] .56	[1] 16.28	14.3	.65	9.27	9.7	.90	8.75	11.3	.81	9.00
1876–1885	25.8	.50	12.82	13.3	.57	7.47	8.8	.72	6.24	10.3	.68	6.92
1886–1895	22.2	.50	11.12	12.4	.53	6.54	10.2	.60	6.13	11.2	.59	6.56
1896–1905	26.4	.51	13.16	13.4	.55	7.34	9.5	.62	5.90	10.5	.61	6.40
1906–1915	30.0	.72	21.74	18.3	.80	14.62	16.7	.87	14.58	14.0	.81	11.41

[1] 9-year average—1867–1875.

Corn, yields per acre and prices, by States—Continued.

Year.	Florida.			Ohio.			Indiana.			Illinois.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	13.2	$1.04	$13.73	38.0	$0.38	$14.44	36.5	$0.31	$11.32	31.6	$0.30	$9.48
1867	11.8	.99	11.68	28.7	.59	16.93	29.2	.47	13.72	23.8	.49	11.66
1868	10.5	1.05	11.02	34.0	.45	15.30	34.0	.39	13.26	34.2	.32	10.94
1869	11.2	1.15	12.88	30.1	.57	17.16	23.2	.55	12.76	23.2	.45	10.44
1870	10.8	1.21	13.07	39.0	.43	16.77	39.5	.34	13.43	35.2	.31	10.91
1871	10.7	.98	10.49	38.5	.40	15.40	35.7	.33	11.78	38.3	.29	11.11
1872	9.6	1.06	10.18	39.5	.30	11.85	38.7	.26	10.06	39.8	.21	8.36
1873	10.4	1.02	10.61	35.0	.39	13.65	25.6	.37	9.47	21.0	.29	6.09
1874	10.6	.89	9.43	36.0	.52	18.72	27.0	.46	12.42	18.0	.50	9.00
1875	10.0	.94	9.40	34.5	.38	13.11	34.0	.34	11.56	34.3	.29	9.95
1876	10.0	.79	7.90	36.7	.35	12.84	30.0	.31	9.30	25.0	.28	7.00
1877	12.9	.69	8.90	31.5	.39	12.28	30.0	.33	9.90	29.0	.28	8.12
1878	9.0	.73	6.57	34.9	.33	11.52	32.8	.27	8.86	27.1	.25	6.78
1879	8.5	.81	6.88	35.0	.39	13.65	33.0	.34	11.22	35.0	.31	10.85
1880	9.4	.85	7.99	37.5	.41	15.38	29.0	.40	11.60	27.2	.36	9.79
1881	8.8	1.00	8.80	25.4	.61	15.49	21.8	.60	13.08	19.4	.58	11.25
1882	9.5	.80	7.60	31.3	.62	19.41	31.3	.48	15.02	23.0	.47	10.81
1883	8.5	.82	6.97	26.1	.47	12.27	27.0	.41	11.07	25.0	.40	10.00
1884	9.5	.80	7.60	30.0	.41	12.30	29.0	.34	9.86	30.0	.31	9.30
1885	9.0	.70	6.30	37.1	.32	11.87	35.5	.29	10.30	31.4	.28	8.79
1886	10.4	.71	7.38	32.2	.35	11.27	31.9	.32	10.21	24.5	.31	7.60
1887	10.6	.71	7.53	26.3	.48	12.62	20.0	.45	9.00	19.2	.41	7.87
1888	9.8	.65	6.37	32.5	.35	11.38	34.8	.31	10.79	35.7	.29	10.35
1889	10.7	.58	6.21	29.6	.31	9.18	29.0	.27	7.83	32.3	.24	7.75
1890	9.3	.75	6.98	23.5	.51	11.98	24.7	.47	11.61	26.2	.43	11.27
1891	11.0	.80	8.80	32.0	.41	13.12	33.3	.38	12.65	33.5	.37	12.40
1892	9.0	.60	5.40	29.4	.42	12.35	29.3	.40	11.72	26.2	.37	9.69
1893	9.7	.68	6.60	23.8	.40	9.52	24.7	.36	8.89	25.7	.31	7.97
1894	10.1	.71	7.17	26.3	.43	11.31	28.9	.37	10.69	28.8	.39	11.23
1895	11.2	.47	5.26	32.6	.27	8.80	32.8	.23	7.54	37.4	.22	8.23
1896	10.0	.53	5.30	41.0	.21	8.61	35.0	.19	6.65	40.5	.18	7.29
1897	8.0	.55	4.40	32.5	.25	8.12	30.0	.21	6.30	32.5	.21	6.82
1898	9.0	.50	4.50	37.0	.27	9.99	36.0	.25	9.00	30.0	.25	7.50
1899	10.0	.53	5.30	36.0	.30	10.80	38.0	.27	10.26	36.0	.26	9.36
1900	8.0	.60	4.80	37.0	.34	12.58	38.0	.32	12.16	37.0	.32	11.84
1901	9.0	.85	7.65	26.1	.57	14.88	19.8	.55	10.89	21.4	.57	12.20
1902	8.6	.77	6.62	38.0	.42	15.96	37.9	.36	13.64	38.7	.36	13.93
1903	9.9	.73	7.23	29.6	.47	13.91	33.2	.36	11.95	32.2	.36	11.59
1904	10.7	.75	8.02	32.5	.46	14.95	31.5	.41	12.92	36.5	.39	14.24
1905	10.1	.66	6.67	37.8	.43	16.25	40.7	.38	15.47	39.8	.38	15.12
1906	11.0	.62	6.82	42.6	.39	16.61	39.6	.36	14.26	36.1	.36	13.00
1907	11.3	.80	9.04	34.6	.52	17.99	36.0	.45	16.20	36.0	.44	15.84
1908	10.5	.82	8.61	38.5	.63	24.26	30.3	.60	18.18	31.6	.57	18.01
1909	12.6	.83	10.46	39.5	.56	22.12	40.0	.50	20.00	35.9	.52	18.67
1910	13.0	.85	11.05	36.5	.46	16.79	39.3	.40	15.72	39.1	.38	14.86
1911	14.6	.80	11.68	38.6	.58	22.39	36.0	.54	19.44	33.0	.55	18.15
1912	13.0	.79	10.27	42.8	.45	19.26	40.3	.42	16.93	40.0	.41	16.40
1913	15.0	.82	12.30	37.5	.63	23.62	36.0	.60	21.60	27.0	.63	17.01
1914	16.0	.80	12.80	39.1	.61	23.85	33.0	.58	19.14	29.0	.61	17.69
1915	15.0	.73	10.95	41.5	.56	23.24	38.0	.51	19.38	36.0	.54	19.44
10-YEAR AVERAGE.												
1866–1875	10.9	1.03	11.25	35.3	.44	15.33	3.23	.38	11.98	29.9	.34	9.79
1876–1885	9.5	.80	7.55	32.6	.43	13.70	26.9	.38	11.02	27.2	.35	9.27
1886–1895	10.2	.67	6.77	28.8	.39	11.15	28.9	.36	10.09	29.0	.33	9.44
1896–1905	9.3	.65	6.05	34.8	.37	12.60	34.0	.33	10.92	34.5	.33	10.99
1906–1915	13.2	.79	10.40	39.1	.54	21.01	36.9	.50	18.08	34.4	.50	16.91

Corn, yields per acre and prices, by States—Continued.

Year.	Michigan.			Wisconsin.			Minnesota.			Iowa.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	32.0	$0.57	$18.24	28.3	$0.57	$16.13	......	......	......	31.5	$0.31	$9.76
1867	31.4	.69	21.67	33.6	.62	20.83	30.0	$0.77	$23.10	33.8	.39	13.18
1868	33.0	.57	18.81	33.0	.43	14.19	33.5	.48	16.08	37.0	.28	10.36
1869	28.9	.59	17.05	26.4	.52	13.73	29.1	.50	14.55	33.2	.40	13.28
1870	37.0	.49	18.13	38.0	.47	17.86	33.0	.46	15.18	32.0	.31	9.92
1871	32.4	.53	17.17	37.7	.39	14.70	37.3	.40	14.92	42.5	.21	8.92
1872	36.0	.38	13.68	38.0	.35	13.30	35.2	.32	11.26	39.8	.16	6.37
1873	31.0	.43	13.33	30.0	.41	12.30	31.5	.38	11.97	29.0	.29	8.41
1874	27.0	.59	15.93	28.2	.56	15.79	31.0	.46	14.26	29.2	.39	11.39
1875	33.0	.53	17.49	21.0	.47	9.87	29.2	.37	10.80	35.0	.24	8.40
1876	29.0	.48	13.92	34.0	.38	12.92	25.4	.37	9.40	30.0	.23	6.90
1877	31.0	.38	11.78	28.0	.32	8.96	29.0	.37	10.73	32.5	.24	7.80
1878	37.4	.38	14.21	37.5	.29	10.88	38.1	.29	11.05	37.4	.16	5.98
1879	37.0	.45	16.65	39.0	.39	15.21	35.0	.27	9.45	38.0	.24	9.12
1880	40.7	.46	18.72	33.0	.39	12.87	35.0	.36	12.60	38.0	.26	9.88
1881	28.0	.63	17.64	27.6	.54	14.90	32.0	.53	16.96	25.8	.44	11.35
1882	30.7	.59	18.11	28.8	.53	15.26	32.0	.45	14.40	25.9	.38	9.84
1883	23.5	.52	12.22	21.0	.48	10.08	20.8	.43	8.94	24.3	.32	7.78
1884	28.0	.40	11.20	24.6	.34	8.36	33.5	.33	11.06	34.5	.23	7.94
1885	32.7	.34	11.12	30.1	.34	10.23	28.4	.32	9.09	32.1	.24	7.70
1886	29.1	.38	11.06	25.7	.37	9.51	29.8	.34	10.13	25.1	.30	7.53
1887	22.5	.48	10.80	25.3	.42	10.63	29.8	.37	11.03	25.5	.35	8.92
1888	30.0	.42	12.60	30.6	.36	11.02	29.3	.32	9.38	35.8	.24	8.59
1889	23.5	.37	8.70	26.3	.29	7.63	28.5	.27	7.70	39.5	.19	7.50
1890	26.7	.55	14.68	30.0	.45	13.50	27.7	.42	11.63	26.0	.41	10.66
1891	29.5	.48	14.16	26.7	.44	11.75	26.5	.39	10.34	36.7	.30	11.01
1892	25.0	.46	11.50	27.3	.38	10.37	27.0	.37	9.99	28.3	.32	9.06
1893	23.7	.45	10.66	29.8	.35	10.43	28.3	.34	9.62	33.9	.27	9.15
1894	23.2	.50	11.60	20.7	.45	9.32	18.4	.43	7.91	15.0	.45	6.75
1895	33.8	.32	10.82	31.8	.30	9.54	31.2	.20	6.24	35.1	.18	6.32
1896	38.0	.24	9.12	37.0	.22	8.14	30.5	.19	5.80	39.0	.14	5.46
1897	31.5	.27	8.50	33.0	.25	8.25	26.0	.24	6.24	29.0	.17	4.93
1898	34.0	.34	11.56	35.0	.28	9.80	32.0	.24	7.68	35.0	.23	8.05
1899	25.0	.36	9.00	35.0	.30	10.50	33.0	.24	7.92	31.0	.23	7.13
1900	36.0	.37	13.32	40.0	.33	13.20	33.0	.29	9.57	38.0	.27	10.26
1901	34.5	.52	17.94	27.4	.52	14.25	26.3	.45	11.84	25.0	.52	13.00
1902	26.4	.52	13.73	28.2	.50	14.10	22.8	.40	9.12	32.0	.33	10.56
1903	33.5	.46	15.41	29.3	.43	12.60	28.3	.38	10.75	28.0	.38	10.64
1904	28.6	.52	14.87	29.7	.46	13.66	26.9	.36	9.68	32.6	.33	10.76
1905	34.0	.46	15.64	37.6	.42	15.79	32.5	.33	10.72	34.8	.34	11.83
1906	37.0	.44	16.28	41.2	.41	16.89	33.6	.34	11.42	39.5	.32	12.64
1907	30.1	.55	16.56	32.0	.55	17.60	27.0	.50	13.50	29.5	.43	12.68
1908	31.8	.64	20.35	33.7	.61	20.56	29.0	.55	15.95	31.7	.52	16.48
1909	35.4	.61	21.59	33.0	.60	19.80	34.8	.49	17.05	31.5	.49	15.44
1910	32.4	.53	17.17	32.5	.52	16.90	32.7	.45	14.72	36.3	.36	13.07
1911	33.0	.65	21.45	36.3	.60	21.78	33.7	.53	17.86	31.0	.53	16.43
1912	34.0	.57	19.38	35.7	.51	18.21	34.5	.37	12.76	43.0	.35	15.05
1913	33.5	.67	22.44	40.5	.60	24.30	40.0	.53	21.20	34.0	.60	20.40
1914	36.0	.67	24.12	40.5	.65	26.32	35.0	.52	18.20	38.0	.55	20.90
1915	32.0	.68	21.76	23.0	.68	15.64	23.0	.62	14.26	30.0	.51	15.30
10-YEAR AVERAGE.												
1866–1875	32.2	.54	17.15	31.4	.48	14.87	[1] 32.2	[1] .46	[1] 14.68	34.3	.30	10.00
1876–1885	31.8	.46	14.56	30.4	.40	11.97	30.9	.37	11.37	31.9	.27	8.43
1886–1895	26.7	.44	11.66	27.4	.38	10.37	27.7	.34	9.40	30.1	.30	8.55
1896–1905	32.2	.41	12.91	33.2	.37	12.03	29.1	.31	8.93	32.4	.29	9.26
1906–1915	33.5	.60	20.11	34.8	.57	19.80	32.3	.49	15.69	34.4	.47	15.84

[1] 9-year average—1867–1875.

Corn, yields per acre and prices, by States—Continued.

Year.	Missouri.			North Dakota.			South Dakota.			Nebraska.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	30.8	$0.40	$12.32	......	......	......	......	......	......	29.3	$0.47	$13.77
1867	27.2	.47	12.78	......	......	......	......	......	......	36.0	.53	19.08
1868	30.3	.42	12.73	......	......	......	......	......	......	22.9	.51	11.68
1869	30.6	.48	14.69	......	......	......	......	......	......	42.2	.29	12.24
1870	31.4	.39	12.25	......	......	......	......	......	......	29.9	.32	9.57
1871	38.0	.28	10.64	......	......	......	......	......	......	41.5	.22	9.13
1872	37.0	.28	10.36	......	......	......	......	......	......	37.8	.16	6.05
1873	23.5	.35	8.22	......	......	......	......	......	......	35.0	.26	9.10
1874	16.0	.67	10.72	......	......	......	......	......	......	10.0	.66	6.60
1875	36.6	.24	8.78	......	......	......	......	......	......	40.0	.17	6.80
1876	27.8	.26	7.23	......	......	......	......	......	......	30.0	.25	7.50
1877	29.0	.26	7.54	......	......	......	......	......	......	38.0	.18	6.84
1878	26.2	.26	6.81	......	......	......	......	......	......	42.0	.16	6.72
1879	37.0	.25	9.25	......	......	......	......	......	......	41.0	.21	8.61
1880	28.4	.36	10.22	......	......	......	......	......	......	31.0	.25	7.75
1881	16.5	.65	10.72	......	......	......	......	......	......	27.4	.39	10.69
1882	29.5	.39	11.50	[1]25.0	$0.51	$12.75	[1]25.0	$0.51	$12.75	34.9	.33	11.52
1883	27.5	.35	9.62	[1]18.2	.45	8.19	[1]18.2	.45	8.19	36.0	.24	8.64
1884	33.0	.26	8.58	[1]30.0	.30	9.00	[1]30.0	.30	9.00	37.7	.18	6.79
1885	31.3	.25	7.82	[1]28.9	.28	8.09	[1]28.9	.28	8.09	36.7	.19	6.97
1886	22.2	.31	6.88	[1]23.9	.37	8.84	[1]23.9	.37	8.84	27.4	.20	5.48
1887	22.0	.37	8.14	[1]33.0	.35	11.55	[1]33.0	.35	11.55	24.1	.30	7.23
1888	31.0	.30	9.30	[1]25.5	.33	8.42	[1]25.5	.33	8.42	35.2	.22	7.74
1889	32.2	.23	7.41	[1]18.0	.33	5.94	[1]18.0	.33	5.94	36.5	.17	6.20
1890	25.8	.44	11.35	[1]13.6	.50	6.80	[1]13.6	.50	6.80	18.0	.48	8.64
1891	29.9	.38	11.36	18.0	.40	7.20	22.5	.35	7.88	35.2	.26	9.15
1892	27.7	.36	9.97	21.4	.40	8.56	22.3	.33	7.36	28.2	.28	7.90
1893	27.9	.30	8.37	20.7	.38	7.87	23.7	.25	5.92	25.2	.27	6.80
1894	22.0	.40	8.80	19.2	.44	8.45	4.2	.46	1.93	6.0	.50	3.00
1895	36.0	.20	7.20	21.3	.24	5.11	11.1	.23	2.55	16.1	.18	2.90
1896	27.0	.20	5.40	35.0	.25	8.75	26.0	.18	4.68	37.5	.13	4.88
1897	26.0	.24	6.24	17.0	.32	5.44	24.0	.21	5.04	30.0	.17	5.10
1898	26.0	.27	7.02	19.0	.36	6.84	28.0	.23	6.44	21.0	.22	4.62
1899	26.0	.30	7.80	23.0	.33	7.59	26.0	.26	6.76	28.0	.23	6.44
1900	28.0	.32	8.96	16.0	.42	6.72	27.0	.29	7.83	26.0	.31	8.06
1901	10.1	.67	6.77	22.6	.46	10.40	21.0	.45	9.45	14.1	.54	7.61
1902	39.0	.33	12.87	19.4	.45	8.73	18.9	.41	7.75	32.3	.30	9.69
1903	32.4	.34	11.02	25.2	.42	10.58	27.2	.35	9.52	26.0	.28	7.28
1904	26.2	.44	11.53	21.2	.40	8.48	28.1	.36	10.12	32.8	.33	10.82
1905	33.8	.37	12.51	27.5	.36	9.90	31.8	.31	9.86	32.8	.32	10.50
1906	32.3	.38	12.27	27.8	.39	10.84	33.5	.29	9.72	34.1	.29	9.89
1907	31.0	.47	14.57	20.0	.60	12.00	25.5	.46	11.73	24.0	.41	9.84
1908	27.0	.57	15.39	23.8	.60	14.28	29.7	.50	14.85	27.0	.51	13.77
1909	26.4	.59	15.58	31.0	.55	17.05	31.7	.50	15.85	24.8	.50	12.40
1910	33.0	.44	14.52	14.0	.58	8.12	25.0	.40	10.00	25.8	.36	9.29
1911	26.0	.60	15.60	25.0	.60	15.00	22.0	.53	11.66	21.0	.55	11.55
1912	32.0	.46	14.72	26.7	.43	11.48	30.6	.37	11.32	24.0	.37	8.88
1913	17.5	.74	12.95	28.8	.52	14.98	25.5	.56	14.28	15.0	.65	9.75
1914	22.0	.68	14.96	28.0	.58	16.24	26.0	.50	13.00	24.5	.53	12.98
1915	29.5	.57	16.82	14.0	.67	9.38	29.0	.49	14.21	30.0	.47	14.10
10-YEAR AVERAGE.												
1866–1875	30.1	.40	11.35	......	......	......	......	......	......	32.5	.36	10.40
1876–1885	28.6	.33	8.93	......	......	......	......	......	......	35.5	.24	8.20
1886–1895	27.7	.33	8.88	21.5	.37	7.87	19.8	.35	6.72	25.2	.29	6.50
1896–1905	27.4	.35	9.01	22.6	.38	8.34	25.8	.30	7.74	28.0	.28	7.50
1906–1915	27.7	.55	14.74	23.9	.55	12.94	27.8	.46	12.66	25.0	.46	11.24

[1] Dakota Territory.

Corn, yields per acre and prices, by States—Continued.

Yield.	Kansas.			Kentucky.			Tennessee.			Alabama.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	34.2	$0.44	$15.05	31.8	$0.34	$10.81	22.0	$0.54	$11.88	9.0	$1.05	$9.45
1867	38.6	.39	15.05	24.7	.47	11.61	23.7	.39	9.24	16.2	.57	9.23
1868	18.0	.74	13.32	32.7	.35	11.44	25.3	.36	9.11	10.8	.64	6.91
1869	48.4	.35	16.94	25.0	.52	13.00	20.0	.61	12.20	15.0	.90	13.50
1870	28.0	.52	14.56	32.1	.43	13.80	25.8	.42	10.84	17.5	.83	14.52
1871	40.0	.26	10.40	27.3	.42	11.47	23.0	.46	10.58	14.5	.83	12.04
1872	38.5	.19	7.32	31.2	.33	10.30	23.5	.43	10.10	17.6	.69	12.14
1873	39.1	.29	11.34	29.5	.41	12.10	22.5	.53	11.92	14.5	.77	11.16
1874	10.5	.82	8.61	25.0	.50	12.50	16.8	.61	10.25	12.3	.84	10.33
1875	40.0	.20	8.00	33.3	.36	11.99	26.5	.36	9.54	12.6	.65	8.19
1876	43.5	.22	9.57	33.5	.27	9.04	24.5	.29	7.10	13.0	.44	5.72
1877	36.5	.20	7.30	30.3	.31	9.39	25.0	.39	9.75	12.0	.66	7.92
1878	33.9	.19	6.44	22.7	.40	9.08	19.3	.41	7.91	12.0	.59	7.08
1879	33.0	.27	8.91	32.0	.37	11.84	25.0	.37	9.25	13.0	.66	8.58
1880	29.3	.29	8.50	29.1	.38	11.06	22.4	.36	8.06	12.4	.67	8.31
1881	18.2	.58	10.56	17.0	.70	11.90	12.4	.72	8.93	9.9	.97	9.60
1882	33.7	.37	12.47	24.3	.52	12.64	24.1	.42	10.12	13.9	.60	8.34
1883	36.7	.26	9.54	24.0	.42	10.08	20.0	.44	8.80	11.5	.64	7.36
1884	36.9	.22	8.12	22.1	.43	9.50	20.3	.45	9.14	13.0	.61	7.93
1885	32.4	.24	7.78	25.5	.35	8.92	21.2	.39	8.27	13.4	.55	7.37
1886	21.8	.27	5.89	25.2	.34	8.57	20.7	.40	8.28	12.1	.60	7.26
1887	14.6	.37	5.40	18.3	.53	9.70	21.5	.50	10.75	13.6	.54	7.34
1888	26.7	.26	6.94	25.8	.34	8.77	20.8	.42	8.74	12.7	.55	6.98
1889	35.3	.18	6.35	26.5	.34	9.01	22.0	.37	8.14	13.5	.51	6.88
1890	15.6	.51	7.96	22.6	.49	11.07	18.8	.52	9.78	10.2	.68	6.94
1891	26.7	.34	9.08	30.0	.10	12.00	22.7	.43	9.76	12.7	.63	8.00
1892	24.5	.31	7.60	23.3	.40	9.32	20.3	.43	8.73	12.2	.52	6.34
1893	21.3	.31	6.60	23.5	.43	10.10	21.3	.39	8.31	11.5	.59	6.78
1894	11.2	.43	4.82	23.0	.44	10.12	21.9	.39	8.54	13.7	.53	7.26
1895	24.3	.19	4.62	31.2	.27	8.42	25.0	.27	6.75	15.9	.37	5.88
1896	28.0	.18	5.04	28.0	.25	7.00	23.0	.28	6.44	12.5	.45	5.62
1897	18.0	.22	3.96	23.0	.35	8.05	21.0	.36	7.56	12.0	.46	5.52
1898	16.0	.26	4.16	31.0	.27	8.37	26.0	.29	7.54	15.0	.41	6.15
1899	27.0	.25	6.75	21.0	.37	7.77	20.0	.39	7.80	12.0	.47	5.64
1900	19.0	.32	6.08	26.0	.40	10.40	20.0	.49	9.80	11.0	.58	6.38
1901	7.8	.63	4.91	15.6	.61	9.52	14.2	.65	9.23	10.9	.77	8.39
1902	29.9	.34	10.17	27.0	.42	11.34	21.9	.47	10.29	8.4	.67	5.63
1903	25.6	.36	9.22	26.6	.56	14.90	23.5	.49	11.52	14.8	.57	8.44
1904	20.9	.41	8.57	26.9	.49	13.18	25.0	.50	12.50	15.0	.60	9.00
1905	27.7	.33	9.14	29.7	.43	12.77	24.6	.50	12.30	14.8	.64	9.47
1906	28.9	.32	9.25	33.0	.42	13.86	28.1	.47	13.21	16.0	.64	10.24
1907	22.1	.44	9.72	28.2	.53	14.95	26.0	.57	14.82	15.5	.75	11.62
1908	22.0	.55	12.10	25.2	.65	16.38	24.8	.64	15.87	14.7	.83	12.20
1909	19.9	.54	10.75	29.0	.62	17.98	22.0	.70	15.40	13.5	.85	11.48
1910	19.0	.45	8.55	29.0	.53	15.37	25.9	.56	14.50	18.0	.71	12.78
1911	14.5	.63	9.14	26.0	.63	16.38	26.8	.61	16.35	18.0	.78	14.04
1912	23.0	.40	9.20	30.4	.55	16.72	26.5	.61	16.16	17.2	.79	13.59
1913	3.2	.78	2.50	20.5	.76	15.58	20.5	.77	15.78	17.3	.89	15.40
1914	18.5	.63	11.66	25.0	.64	16.00	24.0	.68	16.32	17.0	.80	13.60
1915	31.0	.51	15.81	30.0	.56	16.80	27.0	.58	15.66	17.0	.69	11.73
10-YEAR AVERAGE.												
1866–1875	33.5	.42	12.06	29.3	.41	11.90	22.9	.47	10.57	14.0	.78	10.75
1876–1885	33.4	.28	8.92	26.0	.42	10.34	21.4	.42	8.73	12.4	.64	7.82
1886–1895	22.2	.32	6.53	24.9	.40	9.71	21.5	.41	8.78	12.8	.55	6.97
1896–1905	22.0	.33	6.80	25.5	.42	10.33	21.9	.44	9.50	12.6	.56	7.02
1906–1915	20.2	.52	9.87	27.6	.59	16.00	25.2	.62	15.41	16.4	.77	12.67

Corn, yields per acre and prices, by States—Continued.

Year.	Mississippi.			Louisiana.			Texas.			Oklahoma.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	14.5	$1.09	$15.80	17.0	$0.86	$14.62	26.0	$0.65	$16.90	......	......	......
1867	15.7	.78	12.25	15.6	.79	12.32	28.2	.54	15.23	......	......	......
1868	17.1	.55	9.40	22.0	.56	12.32	25.0	.46	11.50	......	......	......
1869	17.5	.89	15.58	25.0	.86	21.50	29.0	.58	16.82	......	......	......
1870	16.5	.88	14.52	22.5	.99	22.28	26.5	.95	25.18	......	......	......
1871	14.0	.88	12.32	14.4	1.01	14.54	19.0	1.00	19.00	......	......	......
1872	17.5	.78	13.65	18.5	.78	14.43	25.3	.38	9.61	......	......	......
1873	15.5	.78	12.09	16.5	.83	13.70	19.0	.74	14.06	......	......	......
1874	13.8	.91	12.56	15.5	.90	13.95	19.0	.68	12.92	......	......	......
1875	18.0	.63	11.34	15.5	.78	12.09	20.0	.72	14.40	......	......	......
1876	15.0	.50	7.50	17.2	.64	11.01	25.0	.46	11.50	......	......	......
1877	15.0	.60	9.00	17.0	.56	9.52	24.0	.42	10.08	......	......	......
1878	13.0	.64	8.32	19.9	.60	11.94	26.0	.44	11.44	......	......	......
1879	16.0	.62	9.92	15.0	.76	11.40	13.0	1.03	13.39	......	......	......
1880	14.6	.63	9.20	19.0	.61	11.59	25.0	.53	13.25	......	......	......
1881	11.0	.96	10.56	13.0	.98	12.74	11.9	.99	11.78	......	......	......
1882	16.8	.55	9.24	18.5	.60	11.10	19.3	.58	11.19	......	......	......
1883	13.5	.63	8.50	14.2	.66	9.37	17.5	.60	10.50	......	......	......
1884	13.5	.62	8.37	12.7	.67	8.51	16.1	.62	9.98	......	......	......
1885	13.4	.54	7.24	16.8	.53	8.90	20.6	.49	10.09	......	......	......
1886	13.1	.59	7.73	15.6	.55	8.58	15.7	.56	8.79	......	......	......
1887	17.3	.53	9.17	18.0	.51	9.18	17.0	.51	8.67	......	......	......
1888	14.7	.54	7.94	14.8	.53	7.84	19.2	.41	7.87	......	......	......
1889	14.8	.50	7.40	17.5	.51	8.92	18.3	.35	6.40	......	......	......
1890	12.5	.70	8.75	16.0	.70	11.20	15.5	.72	11.16	......	......	......
1891	15.2	.58	8.82	17.3	.60	10.38	19.5	.55	10.72	......	......	......
1892	13.7	.51	6.99	14.8	.50	7.40	21.4	.45	9.63	......	......	......
1893	13.1	.55	7.20	14.2	.57	8.09	17.6	.54	9.50	......	......	......
1894	17.2	.49	8.43	16.2	.62	10.04	19.0	.56	10.64	......	......	......
1895	15.8	.37	5.85	18.1	.40	7.24	26.4	.31	8.18	......	......	......
1896	13.5	.44	5.94	13.0	.45	5.85	9.5	.41	3.90	......	......	......
1897	14.5	.45	6.52	17.0	.45	7.65	18.5	.41	7.58	......	......	......
1898	18.0	.39	7.02	18.0	.41	7.38	25.0	.34	8.50	......	......	......
1899	16.0	.46	7.36	18.0	.44	7.92	18.0	.36	6.48	19.0	$0.20	$3.80
1900	11.0	.58	6.38	17.0	.50	8.50	18.0	.47	8.46	26.0	.26	6.76
1901	10.9	.74	8.07	13.7	.75	10.28	11.6	.80	9.28	9.7	.76	7.37
1902	11.5	.61	7.02	12.5	.66	8.25	8.1	.66	5.35	25.4	.41	10.41
1903	18.4	.54	9.94	20.6	.58	11.95	24.2	.48	11.62	25.5	.39	9.94
1904	19.1	.56	10.70	19.9	.57	11.34	22.6	.52	11.75	30.2	.40	12.08
1905	14.3	.65	9.30	13.7	.61	8.36	21.3	.49	10.44	26.4	.34	8.98
1906	18.5	.61	11.28	17.2	.60	10.32	22.5	.50	11.25	33.3	.31	10.32
1907	17.0	.75	12.75	17.5	.70	12.25	21.0	.60	12.60	24.4	.44	10.74
1908	17.3	.83	14.36	19.8	.70	13.86	25.7	.59	15.16	24.8	.51	12.65
1909	14.5	.81	11.74	23.0	.69	15.87	15.0	.76	11.40	17.0	.55	9.35
1910	20.5	.63	12.92	23.6	.55	12.98	20.6	.63	12.98	16.0	.51	8.16
1911	19.0	.72	13.68	18.5	.70	12.95	9.5	.80	7.60	6.5	.70	4.55
1912	18.3	.71	12.99	18.0	.68	12.24	21.0	.64	13.44	18.7	.41	7.67
1913	20.0	.77	15.40	22.0	.77	16.94	24.0	.82	19.68	11.0	.72	7.92
1914	18.5	.73	13.50	19.3	.75	14.48	19.5	.74	14.43	12.5	.64	8.00
1915	19.0	.65	12.35	20.5	.64	13.12	23.5	.58	13.63	29.5	.46	13.57
10-YEAR AVERAGE.												
1866–1875	16.0	.82	12.95	18.2	.84	15.18	23.7	.67	15.56	......	......	......
1876–1885	14.2	.63	8.78	16.3	.66	10.61	19.8	.62	11.32	......	......	......
1886–1895	14.7	.54	7.83	16.2	.55	8.89	19.0	.50	9.16	......	......	......
1896–1905	14.7	.54	7.82	16.3	.54	8.75	17.7	.49	8.34	[1] 23.2	[1] .39	[1] 8.48
1906–1915	18.3	.72	13.10	19.9	.68	13.50	20.2	.67	13.22	19.4	.52	9.29

[1] 7-year average.

Corn, yields per acre and prices, by States—Continued.

Year.	Arkansas.			Montana.			Wyoming.			Colorado.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	24.0	$0.79	$18.96	......	......	......	......	......	......	......	......	......
1867	26.5	.55	14.58	......	......	......	......	......	......	......	......	......
1868	30.5	.47	14.34	......	......	......	......	......	......	......	......	......
1869	28.0	.73	20.44	......	......	......	......	......	......	......	......	......
1870	31.8	.72	22.90	......	......	......	......	......	......	......	......	......
1871	26.7	.59	15.75	......	......	......	......	......	......	......	......	......
1872	23.5	.65	15.28	......	......	......	......	......	......	......	......	......
1873	23.5	.74	17.39	......	......	......	......	......	......	......	......	......
1874	12.6	.86	10.84	......	......	......	......	......	......	......	......	......
1875	30.0	.45	13.50	......	......	......	......	......	......	......	......	......
1876	24.0	.36	8.64	......	......	......	......	......	......	......	......	......
1877	24.0	.43	10.32	......	......	......	......	......	......	......	......	......
1878	24.0	.48	11.52	......	......	......	......	......	......	......	......	......
1879	24.0	.58	13.92	......	......	......	......	......	......	......	......	......
1880	25.0	.49	12.25	......	......	......	......	......	......	18.5	$0.77	$14.24
1881	14.8	.94	13.91	......	......	......	......	......	......	25.5	1.05	26.78
1882	21.6	.46	9.94	36.6	$1.05	$38.43	......	......	......	20.0	.90	18.00
1883	17.5	.53	9.28	20.0	.90	18.00	......	......	......	25.0	.85	21.25
1884	18.5	.54	9.99	21.9	.75	18.68	......	......	......	28.1	.65	18.26
1885	20.2	.46	9.29	25.0	.80	20.00	......	......	......	34.5	.68	23.46
1886	20.4	.49	10.00	24.7	.65	16.06	......	......	......	31.5	.50	15.75
1887	20.0	.50	10.00	27.5	.60	16.50	......	......	......	30.0	.63	18.90
1888	19.5	.48	9.36	......	......	......	......	......	......	22.6	.57	12.88
1889	20.0	.43	8.60	......	......	......	......	......	......	25.4	.58	14.73
1890	16.7	.65	10.86	......	......	......	......	......	......	18.2	.63	11.47
1891	21.2	.46	9.75	......	......	......	......	......	......	21.5	.53	11.40
1892	17.5	.47	8.22	19.4	.68	13.19	18.5	$0.61	$11.28	22.3	.40	8.92
1893	16.2	.45	7.29	27.5	.70	19.25	18.5	.63	11.66	16.5	.51	8.42
1894	19.2	.47	9.02	32.7	.82	26.81	30.0	.65	19.50	19.7	.61	12.02
1895	21.5	.32	6.88	25.0	.75	18.75	27.5	.57	15.68	20.7	.41	8.49
1896	13.5	.37	5.00	26.0	.60	15.60	25.0	.78	19.50	16.0	.36	5.76
1897	16.0	.40	6.40	18.0	.65	11.70	12.0	.50	6.00	19.0	.38	7.22
1898	20.0	.29	5.80	28.0	.66	18.48	16.0	.55	8.80	18.0	.40	7.20
1899	20.0	.38	7.60	23.0	.52	11.96	22.0	.43	9.46	17.0	.43	7.31
1900	19.0	.43	8.17	15.0	.59	8.85	34.0	.60	20.40	19.0	.48	9.12
1901	8.1	.81	6.56	25.0	.90	22.50	39.5	.72	28.44	17.1	.74	12.65
1902	21.3	.49	10.44	22.0	.72	15.84	19.8	.59	11.68	16.5	.59	9.74
1903	20.9	.51	10.66	24.1	.62	14.94	19.4	.58	11.25	19.8	.54	10.69
1904	21.6	.53	11.45	22.2	.68	15.10	32.5	.57	18.52	20.5	.54	11.07
1905	17.3	.55	9.52	19.4	.68	13.19	26.9	.75	20.18	23.8	.47	11.19
1906	23.6	.47	11.09	23.4	.65	15.21	27.0	.59	15.93	27.9	.50	13.95
1907	17.2	.68	11.70	22.5	.68	15.30	25.0	.70	17.50	23.5	.65	15.28
1908	20.2	.66	13.33	23.4	.90	21.06	28.0	.76	21.28	20.2	.71	14.34
1909	18.0	.72	12.96	35.0	.86	30.10	28.0	.78	21.84	24.2	.70	16.94
1910	24.0	.58	13.92	23.0	.95	21.85	10.0	.66	6.60	19.9	.60	11.94
1911	20.8	.72	14.98	26.5	.80	21.20	15.0	.76	11.40	14.0	.78	10.92
1912	20.4	.67	13.67	25.5	.70	17.85	23.0	.64	14.72	20.8	.50	10.40
1913	19.0	.78	14.82	31.5	.77	24.26	29.0	.80	23.20	15.0	.73	10.95
1914	17.5	.80	14.00	28.0	.76	21.28	25.0	.70	17.50	23.0	.60	13.80
1915	23.0	.64	14.72	28.0	.69	19.32	25.0	.67	16.75	24.0	.55	13.20
10-YEAR AVERAGE.												
1866–1875	25.7	.66	16.40	......	......	......	......	......	......	......	......	......
1876–1885	21.4	.53	10.91	......	......	......	......	......	......	[1] 25.3	[1] .82	[1] 20.33
1886–1895	19.2	.47	9.00	......	......	......	......	......	......	22.8	.54	12.30
1896–1905	17.8	.48	8.16	22.3	.66	14.82	24.7	.61	15.42	18.7	.49	9.20
1906–1915	20.4	.67	13.52	26.7	.78	20.74	23.5	.71	16.67	21.2	.63	13.17

[1] 6-year average—1880–1885.

Corn, yields per acre and prices, by States—Continued.

Year.	New Mexico.			Arizona.			Utah.			Nevada.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	......	......	......	......	......	......	......	......	......	......	......	......
1867	......	......	......	......	......	......	......	......	......	......	......	......
1868	......	......	......	......	......	......	......	......	......	......	......	......
1869	......	......	......	......	......	......	......	......	......	......	......	......
1870	......	......	......	......	......	......	......	......	......	35.0	$1.25	$43.75
1871	......	......	......	......	......	......	......	......	......	32.0	1.50	48.00
1872	......	......	......	......	......	......	......	......	......	33.0	1.50	49.50
1873	......	......	......	......	......	......	......	......	......	30.0	1.60	48.00
1874	......	......	......	......	......	......	......	......	......	29.0	1.50	43.50
1875	......	......	......	......	......	......	......	......	......	29.0	1.08	31.32
1876	......	......	......	......	......	......	......	......	......	28.0	1.00	28.00
1877	......	......	......	......	......	......	......	......	......	......	......	......
1878	......	......	......	......	......	......	......	......	......	......	......	......
1879	......	......	......	......	......	......	......	......	......	......	......	......
1880	......	......	......	......	......	......	......	......	......	20.0	.80	16.00
1881	......	......	......	......	......	......	......	......	......	24.8	1.00	24.80
1882	21.2	$1.10	$23.32	21.0	$1.10	$23.10	20.8	$0.90	$18.72	21.7	.90	19.53
1883	20.0	.83	16.60	20.0	.86	17.20	21.0	.88	18.48	24.9	.40	9.96
1884	20.1	.68	13.67	21.2	.67	14.20	21.7	.70	15.19	25.3	.68	17.20
1885	20.5	.78	15.99	22.1	.75	16.58	29.8	.60	17.88	24.8	.75	18.60
1886	20.0	.70	14.00	22.2	.80	17.76	20.0	.60	12.00	25.7	.76	19.53
1887	19.0	.72	13.68	19.0	.65	12.35	21.6	.75	16.20	27.8	.62	17.24
1888	18.5	.67	12.40	......	......	......	14.5	.63	9.14	......	......	......
1889	20.0	.60	12.00	......	......	......	18.3	.61	11.16	......	......	......
1890	20.0	.73	14.60	......	......	......	21.0	.68	14.28	......	......	......
1891	18.3	.72	13.18	......	......	......	19.0	.60	11.40	......	......	......
1892	20.0	.72	14.40	17.4	.65	11.31	18.1	.58	10.50	......	......	......
1893	25.3	.71	17.96	17.8	.66	11.75	21.5	.58	12.47	......	......	......
1894	19.1	.75	14.32	18.6	1.00	18.60	24.4	.58	14.15	......	......	......
1895	27.2	.56	15.23	26.0	.75	19.50	20.3	.49	9.95	......	......	......
1896	16.0	.55	8.80	......	......	......	25.0	.51	12.75	......	......	......
1897	27.0	.58	15.66	......	......	......	22.0	.55	12.10	......	......	......
1898	21.0	.56	11.76	......	......	......	21.0	.60	12.60	......	......	......
1899	20.0	.58	11.60	......	......	......	20.0	.59	11.80	......	......	......
1900	22.0	.64	14.08	......	......	......	20.0	.63	12.60	......	......	......
1901	31.6	.77	24.33	18.0	.90	16.20	19.4	.90	17.46	......	......	......
1902	22.0	.78	17.16	20.2	1.01	20.40	20.1	.67	13.47	......	......	......
1903	24.0	.75	18.00	22.4	.90	20.16	21.4	.70	14.98	......	......	......
1904	22.7	.78	17.71	23.8	.91	21.66	33.2	.72	23.90	......	......	......
1905	25.3	.69	17.46	27.0	.97	26.19	36.2	.70	25.34	......	......	......
1906	29.4	.72	21.17	29.5	.85	25.08	32.0	.74	23.68	......	......	......
1907	29.0	.72	20.88	37.5	.90	33.75	25.5	.72	18.36	......	......	......
1908	27.0	.80	21.60	33.2	1.05	34.86	29.4	.72	21.17	......	......	......
1909	31.3	.90	28.17	32.1	1.00	32.10	31.4	.87	27.32	......	......	......
1910	23.0	.90	20.70	32.5	1.10	35.75	30.3	.84	25.45	30.0	1.00	30.00
1911	24.7	.84	20.75	33.0	.97	32.01	35.0	.81	28.35	30.5	.90	27.45
1912	22.4	.75	16.80	33.0	1.00	33.00	30.0	.75	22.50	30.0	.98	29.40
1913	18.5	.75	13.88	28.0	1.10	30.80	34.0	.70	23.80	34.0	1.18	40.12
1914	28.0	.80	22.40	32.0	1.20	38.40	35.0	.75	26.25	36.0	1.10	39.60
1915	26.0	.73	18.98	30.0	1.15	34.50	34.0	.80	27.20	35.0	.93	32.55
10-YEAR AVERAGE.												
1866–1875	......	......	......	......	......	......	......	......	......	[1] 31.3	[1] 1.40	[1] 44.01
1876–1885	......	......	......	......	......	......	......	......	......	[2] 24.2	[2] .79	[2] 19.16
1886–1895	20.7	.69	14.18	......	......	......	19.9	.61	12.12	......	......	......
1896–1905	23.2	.67	15.65	[3] 22.3	[3] .94	[3] 20.92	23.8	.66	15.70	......	......	......
1906–1915	25.9	.79	20.53	32.1	1.03	33.02	31.7	.77	24.41	[1] 32.6	[1] 1.02	[1] 33.19

[1] 6-year average. [2] 7-year average. [3] 5-year average.

Corn, yields per acre and prices, by States—Continued.

Year.	Idaho.			Washington.			Oregon.			California.		
	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*			*Bush.*			*Bush.*		
1866	......	......	......	......	......	......	......	......	......	......	......	......
1867	......	......	......	......	......	......	......	......	......	......	......	......
1868	......	......	......	......	......	......	......	......	......	45.0	$1.00	$45.00
1869	......	......	......	......	......	......	35.0	$0.80	$28.00	41.4	.90	37.26
1870	......	......	......	......	......	......	29.7	1.00	29.70	35.6	1.20	42.72
1871	......	......	......	......	......	......	26.6	1.00	26.60	38.0	1.16	44.08
1872	......	......	......	......	......	......	28.0	.93	26.04	35.0	1.00	35.00
1873	......	......	......	......	......	......	30.0	.60	18.00	41.0	.73	29.93
1874	......	......	......	......	......	......	30.5	.94	28.67	36.2	.98	35.48
1875	......	......	......	......	......	......	26.5	.91	24.12	36.3	1.07	38.84
1876	......	......	......	......	......	......	30.0	.90	27.00	33.0	1.07	35.31
1877	......	......	......	......	......	......	26.0	.90	23.40	30.0	.95	28.50
1878	......	......	......	......	......	......	33.3	.92	30.64	34.5	.60	20.70
1879	......	......	......	......	......	......	32.0	.93	29.76	28.0	.79	22.12
1880	......	......	......	......	......	......	23.3	.82	19.11	32.0	.76	24.32
1881	......	......	......	......	......	......	20.2	.75	15.15	27.2	.78	21.22
1882	28.5	$1.05	$29.92	23.4	$0.80	$18.72	23.9	.80	19.12	28.3	.85	24.06
1883	20.0	.90	18.00	23.0	.90	20.70	23.5	.75	17.62	24.5	.85	20.82
1884	20.0	.75	15.00	32.7	.75	24.52	27.8	.62	17.24	30.0	60	18.00
1885	21.5	.82	17.63	26.4	.71	18.74	22.8	.70	15.96	24.7	.68	16.80
1886	21.5	.67	14.40	26.1	.75	19.58	26.7	.75	20.02	27.2	.62	16.86
1887	28.2	.60	16.92	21.9	.67	14.67	27.3	.64	17.47	30.0	.61	18.30
1888	......	......	......	20.0	.58	11.60	22.5	.68	15.30	27.8	.70	19.46
1889	......	......	......	......	......	......	20.0	.65	13.00	28.2	.57	16.07
1890	......	......	......	......	......	......	21.6	.66	14.26	27.5	.65	17.88
1891	......	......	......	......	......	......	27.0	.71	19.17	34.5	.71	24.50
1892	16.8	.69	11.59	18.0	.60	10.80	21.5	.56	12.04	30.3	.55	16.66
1893	19.5	.71	13.84	21.3	.62	13.21	24.7	.47	11.61	37.1	.50	18.55
1894	28.6	.59	16.87	20.8	.69	14.35	25.4	.56	14.22	19.3	.57	11.00
1895	30.7	.62	19.03	17.1	.40	6.84	26.4	.55	14.52	34.5	.53	18.28
1896	......	......	......	14.0	.57	7.98	22.0	.56	12.32	37.0	.53	19.61
1897	......	......	......	18.0	.55	9.90	25.0	.53	13.25	31.5	.56	17.64
1898	......	......	......	12.0	.42	5.04	24.0	.60	14.40	26.0	.62	16.12
1899	......	......	......	23.0	.55	12.65	22.0	.64	14.08	27.0	.60	16.20
1900	......	......	......	20.0	.59	11.80	23.0	.57	13.11	25.0	.61	15.25
1901	23.0	.60	13.80	17.5	.58	10.15	20.8	.57	11.86	31.0	.68	21.08
1902	24.7	.62	15.31	23.0	.65	14.95	23.4	.66	15.44	30.5	.77	23.48
1903	34.5	.57	19.66	23.1	.55	12.70	25.8	.67	17.29	30.7	.74	22.72
1904	29.3	.70	20.51	24.7	.66	16.30	28.8	.61	17.57	28.6	.78	22.31
1905	27.2	.66	17.95	24.2	.60	14.52	23.0	.59	13.57	32.0	.76	24.32
1906	28.3	.56	15.85	25.2	.55	13.86	27.6	.65	17.94	34.9	.67	23.38
1907	30.0	.70	21.00	27.0	.70	18.90	27.5	.74	20.35	34.0	.85	28.90
1908	29.0	.70	20.30	25.5	.76	19.38	27.8	.77	21.41	32.0	.88	28.16
1909	30.6	.75	22.95	27.8	.86	23.91	30.7	.80	24.56	34.8	.91	31.67
1910	32.0	.71	22.72	28.0	.75	21.00	25.5	.80	20.40	37.5	.80	30.00
1911	30.0	.85	25.50	28.5	.79	22.52	28.5	.80	22.80	36.0	.90	32.40
1912	32.8	.70	22.96	27.3	.77	21.02	31.5	.75	23.62	37.0	.85	31.45
1913	32.0	.68	21.76	28.0	.80	22.40	28.5	.70	19.95	33.0	.88	29.04
1914	31.0	.72	22.32	27.0	.73	19.71	30.0	.82	24.60	36.0	.87	31.32
1915	35.0	.65	22.75	27.0	.77	20.79	35.0	.82	28.70	41.0	.88	36.08
10-YEAR AVERAGE.												
1866–1875	......	......	......	......	......	......	[1] 29.5	[1] .89	[1] 25.88	[2] 38.6	[2] 1.00	[2] 38.54
1876–1885	......	......	......	......	......	......	26.3	.81	21.50	29.2	.79	23.18
1886–1895	......	......	......	[1] 20.7	[1] .62	[1] 13.01	24.3	.62	15.16	29.6	.60	17.76
1896–1905	[3] 27.7	[3] .63	[3] 17.45	20.0	.57	11.60	23.8	.60	14.29	29.9	.66	19.87
1906–1915	31.1	.70	21.81	27.1	.75	20.35	29.3	.77	22.43	35.6	.85	30.24

[1] 7-year average. [2] 8-year average. [3] 5-year average.

Corn, yields per acre and prices, by States—Continued.

Year.	The Territories.			Indian Territory.		
	Yield.	Price.	Value.	Yield.	Price.	Value.
	Bush.			*Bush.*		
1866	......	......	......	......	......	......
1867	29.4	$0.90	$26.46	......	......	......
1868	......	......	......	......	......	......
1869	28.0	1.10	30.80	......	......	......
1870	35.9	.99	35.54	......	......	......
1871	30.4	.97	29.49	......	......	......
1872	33.4	.86	28.72	......	......	......
1873	28.5	.97	27.64	......	......	......
1874	28.0	1.00	28.00	......	......	......
1875	26.0	1.02	26.52	......	......	......
1876	25.0	.95	23.75	......	......	......
1877	25.0	.70	17.50	......	......	......
1878	30.0	.60	18.00	......	......	......
1879	30.0	.90	27.00	......	......	......
1880	30.0	.72	21.60	......	......	......
1881	32.2	.95	30.59	......	......	......
1882	......	......	......	......	......	......
1883	......	......	......	......	......	......
1884	......	......	......	......	......	......
1885	......	......	......	......	......	......
1886	......	......	......	......	......	......
1887	......	......	......	......	......	......
1888	......	......	......	......	......	......
1889	......	......	......	......	......	......
1890	......	......	......	......	......	......
1891	......	......	......	......	......	......
1892	......	......	......	......	......	......
1893	......	......	......	......	......	......
1894	......	......	......	......	......	......
1895	......	......	......	......	......	......
1896	......	......	......	......	......	......
1897	......	......	......	......	......	......
1898	......	......	......	......	......	......
1899	......	......	......	......	......	......
1900	......	......	......	......	......	......
1901	......	......	......	12.0	$0.76	$9.12
1902	......	......	......	24.9	.43	10.71
1903	......	......	......	27.7	.39	10.80
1904	......	......	......	32.4	.40	12.96
1905	......	......	......	32.7	.37	12.10
1906	......	......	......	33.6	.32	10.75
1907	......	......	......	......	......	......
1908	......	......	......	......	......	......
1909	......	......	......	......	......	......
1910	......	......	......	......	......	......
1911	......	......	......	......	......	......
1912	......	......	......	......	......	......
1913	......	......	......	......	......	......
1914	......	......	......	......	......	......
1915	......	......	......	......	......	......
10-YEAR AVERAGE.						
1866–1875	[1] 30.0	[1] .98	[1] 29.15	......	......	......
1876–1885	[2] 28.7	[2] .80	[2] 23.07	......	......	......
1866–1895	......	......	......	......	......	......
1896–1905	......	......	......	......	......	......
1906–1915	......	......	......	......	......	......

[1] 8-year average. [2] 6-year average.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 516

Joint Contribution from the Bureau of Plant Industry WM. A. TAYLOR, Chief, and the Office of Markets and Rural Organization, CHARLES J. BRAND, Chief

Washington, D. C. ▼ December 28, 1916

TABLE FOR CONVERTING WEIGHTS OF MECHANICAL SEPARATIONS INTO PERCENTAGES OF THE SAMPLE ANALYZED.[1]

By E. G. Boerner, *Assistant in Grain Standardization.*

INTRODUCTION.

The rules and regulations for the enforcement of the United States Grain Standards Act prescribe a definite procedure for securing a representative sample upon which the grade of any particular lot or parcel of shelled corn is to be based.

The rules provide that the original sample must be not less than 2 quarts in quantity, of which approximately 1⅛ pints must be placed in an air-tight container and the remainder inclosed in a cloth sack. The portion in the container is intended for the determination of the percentage of moisture, and this portion should be used for that test only. The remainder of the sample, contained in a cloth bag, will approximate 2½ pints, and this portion is to be used for the remaining determinations, including color, damaged corn (not including heat damage), heat-damaged corn, and foreign material and cracked corn. The grades specify the maximum and minimum percentages permitted for the factors mentioned, and these percentages are to be determined by weight.

Because of the time involved, it is impracticable to make the mechanical separations for color, damage, and foreign material and cracked corn on the entire 2½ or more pints, and it therefore becomes necessary, in most cases at least, to divide the sample in order to obtain a smaller representative portion for the determination of the factors mentioned.

Experiments have shown that the sample upon which the determinations for color, damage, foreign material, etc., are based should

[1] The work covered by this bulletin was done under the direction of Dr. J. W. T. Duvel, in charge of the Office of Grain Standardization of the Bureau of Plant Industry. Since August 18, 1916, the grain-standardization work of the Department of Agriculture has been administered jointly by the Office of Markets and Rural Organization and the Bureau of Plant Industry in connection with the administration of the United States Grain Standards Act.

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be approximately 250 grams in size. After the mechanical separations and weighings have been made, mathematical calculations are involved in order to convert these weights into terms of percentage, and the accompanying table enables the analyst to accomplish these results without any calculations.

DIRECTIONS FOR USING THE TABLE.

Table I shows percentage equivalents ranging from 0 to 40 for samples weighing from 240 to 260 grams, inclusive, which covers the

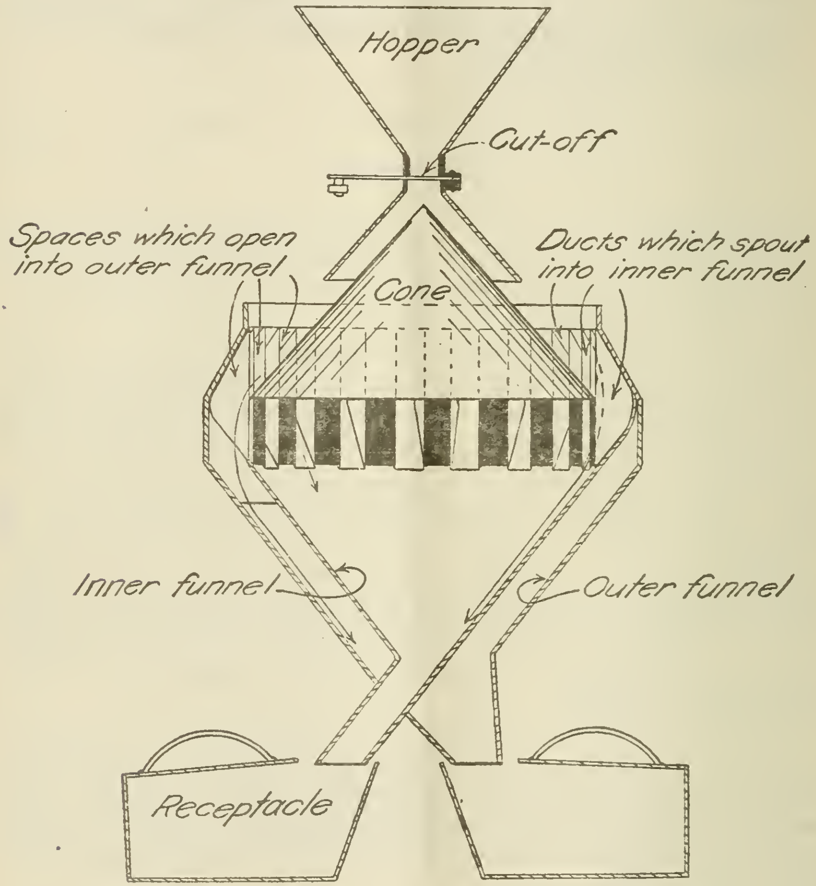

FIG. 1.—A vertical cross section of the sampling device, showing the paths taken by the material in passing from the hopper to the containers.

entire range of corn of other colors, damage, heat damage, and foreign material and cracked corn specified in the numbered Federal Corn Standards.

In using the table to ascertain the percentage equivalent of a certain weight of a separation of damage, etc., always read from left to right.

The solution of the following problem will illustrate the use of the table:

Problem.—A sample weighing 240 grams contains 8 grams of damaged corn. What is the percentage of damaged corn contained in the sample?

Referring to Table I (p. 6), follow down the first column to the figure 8.0 (the weight of the separation of damaged corn in grams). The figure opposite (in the second column, with heading 240) is found to be 3.3, which is the correct percentage expressed to the nearest tenth of 1 per cent.

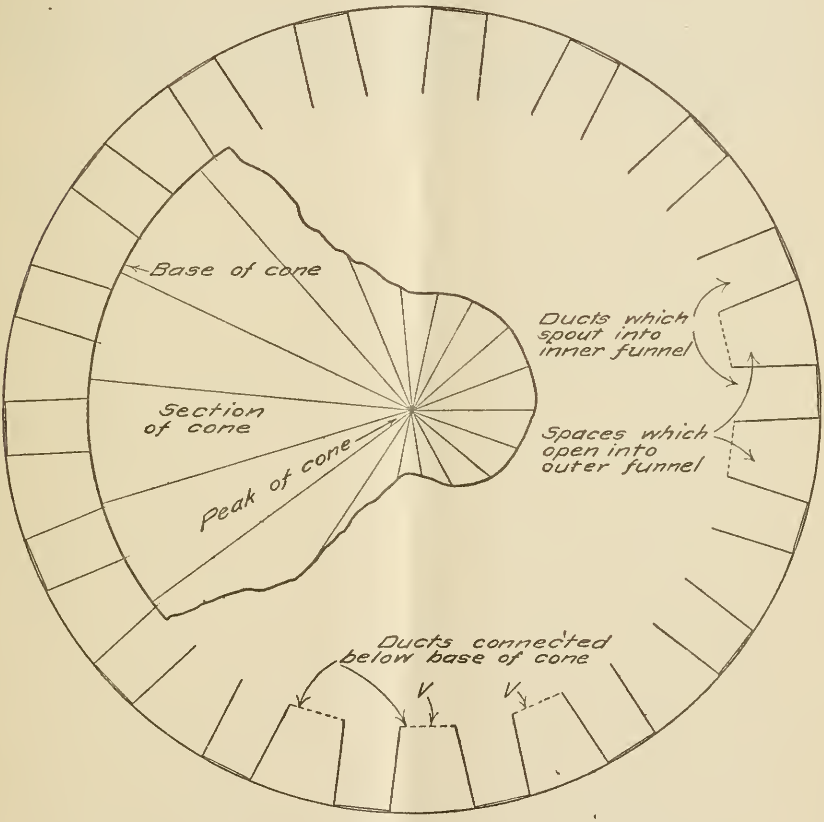

FIG. 2.—Cross section of the sampling device at the base of the cone.

The use of the table will save time in converting the separations into terms of percentages of the whole sample analyzed, and its careful use will prevent errors which often occur in the mathematical calculations involved when the table is not used.

In this connection it is highly essential that extreme care should be taken to preserve the accuracy of the sample when reducing the original $2\frac{1}{2}$ or more pints taken from the bulk grain to the smaller sample of approximately 250 grams for analytical purposes. Experiments have shown that it is almost impossible to divide a large sample into smaller portions and at the same time retain the correct proportion of damage, dirt, color, etc., in the smaller sample unless a device similar to the one described in Bulletin 287 of the United States Department of Agriculture is used. This apparatus was devised to meet the demands of grain and seed dealers, as well as laboratory workers, for securing a reliable grain or seed sample from a larger portion of the material to be examined, analyzed, and graded. Figure 1 shows a vertical cross section of the sampling device, while figure 2 shows a cross section of this device at the base of the cone. A detailed description of this sampling device is contained in the before-mentioned bulletin. This device has been covered by a public-service patent (No. 1,160,036), and anyone in the United States is free to make and use it without the payment of a royalty.

TABLE I.—*Equivalent percentage of a sample of grain, etc., when the weight of the sample analyzed and the weight of the mechanical separation are given.*

Weight of separation.	Weight of sample analyzed (grams).																				
	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
0.1 gram......	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
.2 gram......	.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.3 gram......	.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.4 gram......	.2	.	.	.	.	.	.	.	.	.	.	.1	.	.	.	.	.	.	.	.	.
.5 gram......	.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.6 gram......	.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.7 gram......	.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.8 gram......	.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.9 gram......	.4	.	.	.	.	.	.	.	.	.	.	.3	.	.	.	.	.	.	.	.	.
1.0 gram......	.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1.1 grams.....	.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1.2 grams.....	.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1.3 grams.....	.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1.4 grams.....	.6	.	.	.	.	.	.	.	.	.	.	.5	.	.	.	.	.	.	.	.	.
1.5 grams.....	.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1.6 grams.....	.7	.	.	.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1.7 grams.....	.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.6	.	.
1.8 grams.....	.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1.9 grams.....	.8	.	.	.	.	.	.	.	.	.	.	.7	.	.	.	.	.	.	.	.	.
2.0 grams.....	.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.1 grams.....	.9	.	.	.	.	.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.2 grams.....	.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.8	.	.	.	.
2.3 grams.....	.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.4 grams.....	1.0	.	.	.	.	.	.	.	.	.	.	.9	.	.	.	.	.	.	.	.	.

2.5 grams.....	1.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.6 grams.....	1.1	.	.	.	.	.	1.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.7 grams.....	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.0	.	.	.	.	.
2.8 grams.....	1.2	.	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.9 grams.....	1.2	.	.	.	.	.	.	.	.	.	.	1.1	.	.	.	.	.	.	.	.	.
3.0 grams.....	1.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.1	.
3.1 grams.....	1.3	.	.	.	.	.	.	1.2	.	.	.	.	.	.	.	.	.	.	.	.	.
3.2 grams.....	1.3	.	.	.	.	.	.	.	.	.	.	.	.	.	1.2	.	.	.	.	.	.
3.3 grams.....	1.4	.	.	1.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.4 grams.....	1.4	.	.	.	.	.	.	.	.	.	.	1.3	.	.	.	.	.	.	.	.	.
3.5 grams.....	1.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.3	.	.
3.6 grams.....	1.5	.	.	.	.	.	.	1.4	.	.	.	.	.	.	.	.	.	.	.	.	.
3.7 grams.....	1.5	.	.	.	.	.	.	.	.	.	.	.	.	.	1.4	.	.	.	.	.	.
3.8 grams.....	1.6	.	.	.	1.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.9 grams.....	1.6	.	.	.	.	.	.	.	.	.	.	1.5	.	.	.	.	.	.	.	.	.
4.0 grams.....	1.7	1.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.5	.	.	.
4.1 grams.....	1.7	.	.	.	.	.	.	1.6	.	.	.	.	.	.	.	.	.	.	.	.	.
4.2 grams.....	1.7	.	.	.	.	.	.	.	.	.	.	.	.	.	1.6	.	.	.	.	.	.
4.3 grams.....	1.8	.	.	.	.	1.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.6
4.4 grams.....	1.8	.	.	.	.	.	.	.	.	.	.	1.7	.	.	.	.	.	.	.	.	.
4.5 grams.....	1.9	.	1.8	.	.	.	.	.	.	.	.	.	.	.	.	.	1.7	.	.	.	.
4.6 grams.....	1.9	.	.	.	.	.	.	.	1.8	.	.	.	.	.	.	.	.	.	.	.	.
4.7 grams.....	1.9	.	.	.	.	.	.	.	.	.	.	.	.	1.8	.	.	.		.	.	.
4.8 grams.....	2.0	.	.	.	.	1.9	.	.	.	.	.	.	.	.	.	.	.	.	.	1.8	.
4.9 grams.....	2.0	.	.	.	.	.	.	.	.	.	.	1.9	.	.	.	.	.		.	.	.
5.0 grams.....	2.1	.	.	2.0	.	.	.	.	.	.	.	.	.	.	.	.	1.9		.	.	.

TABLE I.—*Equivalent percentage of a sample of grain, etc., when the weight of the sample analyzed and the weight of the mechanical separation are given*—Continued.

Weight of separation.	Weight of sample analyzed (grams).																				
	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5.1 grams	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
5.2 grams	2.2	2.1	.	.	.	.	.	.	.	.	.	.	.	2.0	.	.	.	.	.	.	.
5.3 grams....	2.2	.	.	.	.	.	2.1	.	.	.	.	.	.	.	.	.	.	.	2.0	.	.
5.4 grams..	2.2	.	.	.	.	.	.	.	.	.	.	2.1	.	.	.	.	.	.	.	.	.
5.5 grams...	2.3	.	.	.	2.2	.	.	.	.	.	.	.	.	.	.	2.1	.	.	.	.	.
5.6 grams...	2.3	.	.	.	.	.	.	.	2.2	.	.	.	.	.	.	.	.	.	.	.	2.1
5.7 grams....	2.4	.	2.3	.	.	.	.	.	.	.	.	.	.	2.2	.	.	.	.	.	.	.
5.8 grams....	2.4	.	.	.	.	.	2.3	.	.	.	.	.	.	.	.	.	.	2.2	.	.	.
5.9 grams....	2.4	.	.	.	.	.	.	.	.	.	.	2.3	.	.	.	.	.	.	.	.	.
6.0 grams....	2.5	.	.	.	2.4	.	.	.	.	.	.	.	.	.	.	2.3	.	.	.	.	.
6.1 grams....	2.5	.	.	.	.	.	.	.	2.4	.	.	.	.	.	.	.	.	.	.	2.3	.
6.2 grams....	2.6	.	.	2.5	.	.	.	.	.	.	.	.	.	2.4	.	.	.	.	.	.	.
6.3 grams....	2.6	.	.	.	.	.	.	2.5	.	.	.	.	.	.	.	.	.	2.4	.	.	.
6.4 grams....	2.7	2.6	.	.	.	.	.	.	.	.	.	2.5	.	.	.	.	.	.	.	.	.
6.5 grams....	2.7	.	.	.	.	2.6	.	.	.	.	.	.	.	.	2.5	.	.	.	.	.	.
6.6 grams....	2.7	.	.	.	.	.	.	.	.	2.6	.	.	.	.	.	.	.	.	2.5	.	.
6.7 grams....	2.8	.	.	2.7	.	.	.	.	.	.	.	.	2.6	.	.	.	.	.	.	.	.
6.8 grams....	2.8	.	.	.	.	.	.	2.7	.	.	.	.	.	.	.	.	2.6	.	.	.	.
6.9 grams....	2.9	.	2.8	.	.	.	.	.	.	.	.	2.7	.	.	.	.	.	.	.	.	2.6
7.0 grams....	2.9	.	.	.	.	2.8	.	.	.	.	.	.	.	.	2.7	.	.	.	.	.	.
7.1 grams....	2.9	.	.	.	.	.	.	.	.	2.8	.	.	.	.	.	.	.	.	2.7	.	.
7.2 grams....	3.0	.	.	.	2.9	.	.	.	.	.	.	.	2.8	.	.	.	.	.	.	.	.
7.3 grams....	3.0	.	.	.	.	.	.	2.9	.	.	.	.	.	.	.	.	2.8	.	.	.	.
7.4 grams....	3.1	.	3.0	.	.	.	.	.	.	.	.	2.9	.	.	.	.	.	.	.	2.8	.

7.5 grams....	3.1	.	.	.	.	.	3.0	.	.	.	.	.	.	.	2.9	.	.	.	.	.	.
7.6 grams....	3.2	3.1	.	.	.	.	.	.	.	3.0	.	.	.	.	.	.	.	2.9	.	.	.
7.7 grams....	3.2	.	.	.	3.1	.	.	.	.	.	.	.	3.0	.	.	.	.	.	.	.	.
7.8 grams....	3.2	.	.	.	.	.	.	3.1	.	.	.	.	.	.	.	3.0	.	.	.	.	.
7.9 grams....	3.3	.	.	3.2	.	.	.	.	.	.	.	3.1	.	.	.	.	.	.	.	3.0	.
8.0 grams....	3.3	.	.	.	.	.	3.2	.	.	.	.	.	.	.	3.1	.	.	.	.	.	.
8.1 grams....	3.4	.	3.3	.	.	.	.	.	.	3.2	.	.	.	.	.	.	.	3.1	.	.	.
8.2 grams....	3.4	.	.	.	.	3.3	.	.	.	.	.	.	3.2	.	.	.	.	.	.	.	3.1
8.3 grams....	3.4	.	.	.	.	.	.	.	3.3	.	.	.	.	.	.	3.2	.	.	.	.	.
8.4 grams....	3.5	.	.	3.4	.	.	.	.	.	.	.	3.3	.	.	.	.	.	.	3.2	.	.
8.5 grams....	3.5	.	.	.	.	.	3.4	.	.	.	.	.	.	3.3	.	.	.	.	.	.	.
8.6 grams....	3.6	.	3.5	.	.	.	.	.	.	3.4	.	.	.	.	.	.	3.3	.	.	.	.
8.7 grams....	3.6	.	.	.	.	3.5	.	.	.	.	.	.	3.4	.	.	.	.	.	.	3.3	.
8.8 grams....	3.7	3.6	.	.	.	.	.	.	3.5	.	.	.	.	.	.	3.4	.	.	.	.	.
8.9 grams....	3.7	.	.	.	3.6	.	.	.	.	.	.	3.5	.	.	.	.	.	.	3.4	.	.
9.0 grams....	3.7	.	.	.	.	.	3.6	.	.	.	.	.	.	3.5	.	.	.	.	.	.	.
9.1 grams....	3.8	.	.	3.7	.	.	.	.	.	3.6	.	.	.	.	.	.	3.5	.	.	.	.
9.2 grams....	3.8	.	.	.	.	3.7	.	.	.	.	.	.	3.6	.	.	.	.	.	.	3.5	.
9.3 grams....	3.9	3.8	.	.	.	.	.	.	3.7	.	.	.	.	.	.	3.6	.	.	.	.	.
9.4 grams....	3.9	.	.	.	3.8	.	.	.	.	.	.	3.7	.	.	.	.	.	3.6	.	.	.
9.5 grams....	3.9	.	.	.	.	.	.	3.8	.	.	.	.	.	3.7	.	.	.	.	.	.	3.6
9.6 grams....	4.0	.	.	3.9	.	.	.	.	.	.	3.8	.	.	.	.	.	3.7	.	.	.	.
9.7 grams....	4.0	.	.	.	.	3.9	.	.	.	.	.	.	3.8	.	.	.	.	.	3.7	.	.
9.8 grams....	4.1	.	4.0	.	.	.	.	.	3.9	.	.	.	.	.	3.8	.	.	.	.	.	.
9.9 grams....	4.1	.	.	.	.	4.0	.	.	.	.	.	3.9	.	.	.	.	.	3.8	.	.	.
10.0 grams....	4.2	4.1	.	.	.	.	.	4.0	.	.	.	.	.	3.9	.	.	.	.	.	.	3.8

TABLE I.—*Equivalent percentage of a sample of grain, etc., when the weight of the sample analyzed and the weight of the mechanical separation are given*—Continued.

Weight of separation.	Weight of sample analyzed (grams).																				
	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
10.1 grams	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9
10.2 grams	4.2	.	.	.	.	.	4.1	.	.	.	4.1	.	4.0	.	.	.	.	.	3.9	.	.
10.3 grams	4.3	.	4.2	.	.	.	.	.	4.1	.	.	.	.	.	4.0	.	.	.	.	.	.
10.4 grams	4.3	.	.	.	.	4.2	.	.	.	.	.	4.1	.	.	.	.	.	4.0	.	.	.
10.5 grams	4.4	4.3	.	.	.	.	.	4.2	.	.	.	.	.	4.1	.	.	.	.	.	4.0	.
10.6 grams	4.4	.	.	.	4.3	.	.	.	.	4.2	.	.	.	.	.	4.1	.	.	.	.	.
10.7 grams	4.4	.	.	.	.	.	4.3	.	.	.	.	.	4.2	.	.	.	.	.	4.1	.	.
10.8 grams	4.5	.	.	4.4	.	.	.	.	4.3	.	.	.	.	.	4.2	.	.	.	.	.	4.1
10.9 grams	4.5	.	.	.	.	4.4	.	.	.	.	.	4.3	.	.	.	.	4.2	.	.	.	.
11.0 grams	4.6	.	4.5	.	.	.	.	4.4	.	.	.	.	.	4.3	.	.	.	.	.	4.2	.
11.1 grams	4.6	.	.	.	4.5	.	.	.	.	4.4	.	.	.	.	.	4.3	.	.	.	.	.
11.2 grams	4.7	4.6	.	.	.	.	4.5	.	.	.	.	.	4.4	.	.	.	.	4.3	.	.	.
11.3 grams	4.7	.	.	4.6	.	.	.	.	4.5	.	.	.	.	.	4.4	.	.	.	.	.	4.3
11.4 grams	4.7	.	.	.	.	4.6	.	.	.	.	.	4.5	.	.	.	.	4.4	.	.	.	.
11.5 grams	4.8	.	4.7	.	.	.	.	4.6	.	.	.	.	.	4.5	.	.	.	.	4.4	.	.
11.6 grams	4.8	.	.	.	4.7	.	.	.	.	4.6	.	.	.	.	.	4.5	.	.	.	.	.
11.7 grams	4.9	4.8	.	.	.	.	4.7	.	.	.	.	.	4.6	.	.	.	.	4.5	.	.	.
11.8 grams	4.9	.	.	4.8	.	.	.	.	4.7	.	.	.	.	.	4.6	.	.	.	.	4.5	.
11.9 grams	4.9	.	.	.	.	4.8	.	.	.	.	.	4.7	.	.	.	.	4.6	.	.	.	.
12.0 grams	5.0	.	4.9	.	.	.	.	4.8	.	.	.	.	.	4.7	.	.	.	.	4.6	.	.
12.1 grams	5.0	.	.	.	4.9	.	.	.	.	4.8	.	.	.	.	.	4.7	.	.	.	.	4.6
12.2 grams	5.1	.	5.0	.	.	.	4.9	.	.	.	.	.	4.8	.	.	.	.	4.7	.	.	.
12.3 grams	5.1	.	.	.	5.0	.	.	.	4.9	.	.	.	.	.	4.8	.	.	.	.	4.7	.
12.4 grams	5.2	5.1	.	.	.	.	5.0	.	.	.	.	4.9	.	.	.	.	4.8	.	.	.	.

12.5 grams....	5.2	.	.	5.1	.	.	.	.	5.0	.	.	.	.	4.9	.	.	.	.	4.8	.	.	4.8
12.6 grams....	5.2	.	.	.	.	5.1	.	.	.	.	5.0	.	.	.	.	4.9	.	.	.	.	.	.
12.7 grams....	5.3	.	5.2	.	.	.	.	5.1	.	.	.	5.0	.	.	.	.	.	4.9	.	.	.	.
12.8 grams....	5.3	.	.	.	5.2	.	.	.	.	5.1	.	.	.	5.0	.	.	.	.	.	4.9	.	.
12.9 grams....	5.4	5.3	.	.	.	.	5.2	.	.	.	.	5.1	.	.	.	5.0	.	.	.	.	.	.
13.0 grams....	5.4	.	.	5.3	.	.	.	.	5.2	.	.	.	5.1	.	.	.	.	5.0	.	.	.	.
13.1 grams....	5.4	.	.	.	.	5.3	.	.	.	.	5.2	.	.	.	5.1	.	.	.	.	5.0	.	.
13.2 grams....	5.5	.	5.4	.	.	.	.	5.3	.	.	.	5.2	.	.	.	.	5.1	.	.	.	.	.
13.3 grams....	5.5	.	.	.	5.4	.	.	.	.	5.3	.	.	.	5.2	.	.	.	.	5.1	.	.	.
13.4 grams....	5.6	.	5.5	.	.	.	5.4	.	.	.	.	5.3	.	.	.	5.2	.	.	.	.	5.1	5.1
13.5 grams....	5.6	.	.	5.5	.	.	.	.	5.4	.	.	.	5.3	.	.	.	.	5.2	.	.	.	.
13.6 grams....	5.7	5.6	.	.	.	5.5	.	.	.	.	5.4	.	.	.	5.3	.	.	.	.	5.2	.	.
13.7 grams....	5.7	.	.	5.6	.	.	.	5.5	.	.	.	5.4	.	.	.	.	5.3	.	.	.	.	.
13.8 grams....	5.7	.	.	.	5.6	.	.	.	.	5.5	.	.	.	5.4	.	.	.	.	5.3	.	.	.
13.9 grams....	5.8	.	5.7	.	.	.	5.6	.	.	.	.	5.5	.	.	.	5.4	.	.	.	.	5.3	5.3
14.0 grams....	5.8	.	.	.	5.7	.	.	.	5.6	.	.	.	5.5	.	.	.	.	5.4	.	.	.	.
14.1 grams....	5.9	5.8	.	.	.	5.7	.	.	.	.	5.6	.	.	.	5.5	.	.	.	.	5.4	.	.
14.2 grams....	5.9	.	.	5.8	.	.	.	5.7	.	.	.	5.6	.	.	.	.	5.5	.	.	.	.	.
14.3 grams....	5.9	.	.	.	.	5.8	.	.	.	5.7	.	.	.	5.6	.	.	.	.	5.5	.	.	.
14.4 grams....	6.0	.	5.9	.	.	.	5.8	.	.	.	.	5.7	.	.	.	5.6	.	.	.	5.5	.	.
14.5 grams....	6.0	.	.	.	5.9	.	.	.	5.8	.	.	.	5.7	.	.	.	.	5.6	.	.	.	.
14.6 grams....	6.1	6.0	.	.	.	5.9	.	.	.	.	5.8	.	.	.	5.7	.	.	.	5.6	.	.	.
14.7 grams....	6.1	.	.	6.0	.	.	.	5.9	.	.	.	5.8	.	.	.	.	5.7	.	.	.	5.6	5.6
14.8 grams....	6.2	6.1	.	.	.	6.0	.	.	.	5.9	.	.	.	5.8	.	.	.	5.7	.	.	.	.
14.9 grams....	6.2	.	6.1	.	.	.	6.0	.	.	.	.	5.9	.	.	.	5.8	.	.	.	5.7	.	.
15.0 grams....	6.2	.	.	.	6.1	.	.	.	6.0	.	.	.	.	5.9	.	.	5.8	.	.	.	.	.

TABLE I.—*Equivalent percentage of a sample of grain, etc., when the weight of the sample analyzed and the weight of the mechanical separation are given*—Continued.

Weight of separation.	Weight of sample analyzed (grams).																				
	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
15.1 grams....	6.3	6.3	6.2	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.8	5.8	5.8
15.2 grams....	6.3	.	.	6.2	.	.	.	6.1	.	.	.	6.0	.	.	.	.	5.9	.	.	.	5.8
15.3 grams....	6.4	6.3	.	.	.	6.2	.	.	.	6.1	.	.	.	6.0	.	.	.	5.9	.	.	.
15.4 grams....	6.4	.	.	6.3	.	.	.	6.2	.	.	.	6.1	.	.	.	6.0	.	.	.	5.9	.
15.5 grams....	6.4	.	.	.	6.3	.	.	.	6.2	.	.	.	6.1	.	.	.	6.0	.	.	.	.
15.6 grams....	6.5	.	6.4	.	.	.	6.3	.	.	.	6.2	.	.	.	6.1	.	.	.	6.0	.	.
15.7 grams....	6.5	.	.	.	6.4	.	.	6.3	.	.	.	6.2	.	.	.	6.1	.	.	.		6.0
15.8 grams.....	6.6	6.5	.	.	.	6.4	.	.	.	6.3	.	.	.	6.2	.	.	.	6.1	.	.	.
15.9 grams....	6.6	.	.	6.5	.	.	.	6.4	.	.	.	6.3	.	.	6.2	.	.	.	.	6.1	.
16.0 grams....	6.7	6.6	.	.	6.5	.	.	.	6.4	.	.	.	6.3	.	.	.	6.2	.	.	.	6.1
16.1 grams....	6.7	.	6.6	.	.	.	6.5	.	.	.	6.4	.	.	.	6.3	.	.	.	6.2	.	.
16.2 grams....	6.7	.	.	.	6.6	.	.	6.5	.	.	.	6.4	.	.	.	6.3	.	.	.	6.2	.
16.3 grams....	6.8	.	6.7	.	.	6.6	.	.	.	6.5	.	.	.	6.4	.	.	.	6.3	.	.	.
16.4 grams....	6.8	.	.	6.7	.	.	.	6.6	.	.	.	6.5	.	.	6.4	.	.	.	6.3	.	.
16.5 grams....	6.9	6.8	.	.	.	6.7	.	.	6.6	.	.	.	6.5	.	.	.	6.4	.	.	.	6.3
16.6 grams....	6.9	.	6.8	.	.	.	6.7	.	.	.	6.6	.	.	.	6.5	.	.	6.4	.	.	.
16.7 grams....	6.9	.	.	.	6.8	.	.	.	6.7	.	.	6.6	.	.	.	6.5	.	.	.	6.4	.
16.8 grams....	7.0	.	6.9	.	.	6.8	.	.	.	6.7	.	.	.	6.6	.	.	.	6.5	.	.	.
16.9 grams....	7.0	.	.	6.9	.	.	.	6.8	.	.	.	6.7	.	.	6.6	.	.	.	6.5	.	.
17.0 grams....	7.1	7.0	.	.	.	6.9	.	.	6.8	.	.	.	6.7	.	.	.	6.6	.	.	.	6.5
17.1 grams....	7.1	.	.	7.0	.	.	6.9	.	.	.	6.8	.	.	6.7	.	.	.	6.6	.	.	.
17.2 grams....	7.2	7.1	.	.	7.0	.	.	.	6.9	.	.	6.8	.	.	.	6.7	.	.	.	6.6	.
17.3 grams....	7.2	.	7.1	.	.	.	7.0	.	.	6.9	.	.	.	6.8	.	.	6.7	.	.	.	6.6
17.4 grams....	7.2	.	.	.	7.1	.	.	7.0	.	.	.	6.9	.	.	6.8	.	.	.	6.7	.	.

17.5 grams....	7.3	.	7.2	.	.	7.1	.	.	7.0	.	.	.	6.9	.	.	.	6.8	.	.	6.7	.
17.6 grams....	7.3	.	.	7.2	.	.	7.1	.	.	.	7.0	.	.	6.9	.	.	.	6.8	.	.	.
17.7 grams....	7.4	7.3	.	.	7.2	.	.	.	7.1	.	.	7.0	.	.	.	6.9	.	.	.	6.8	.
17.8 grams....	7.4	.	7.3	.	.	.	7.2	.	.	7.1	.	.	.	7.0	.	.	6.9	.	.	.	6.8
17.9 grams....	7.4	.	.	.	7.3	.	.	7.2	.	.	.	7.1	.	.	7.0	.	.	.	6.9	.	.
18.0 grams....	7.5	.	7.4	.	.	7.3	.	.	7.2	.	.	.	7.1	.	.	7.0	.	.	.	6.9	.
18.1 grams....	7.5	.	.	7.4	.	.	7.3	.	.	.	7.2	.	.	7.1	.	.	.	7.0	.	.	.
18.2 grams....	7.6	7.5	.	.	7.4	.	.	.	7.3	.	.	7.2	.	.	.	7.1	.	.	7.0	.	.
18.3 grams....	7.6	.	.	7.5	.	.	7.4	.	.	7.3	.	.	.	7.2	.	.	7.1	.	.	.	7.0
18.4 grams....	7.7	7.6	.	.	7.5	.	.	7.4	.	.	.	7.3	.	.	7.2	.	.	7.1	.	.	.
18.5 grams....	7.7	.	7.6	.	.	7.5	.	.	7.4	.	.	.	7.3	.	.	7.2	.	.	.	7.1	.
18.6 grams....	7.7	.	.	7.6	.	.	.	7.5	.	.	7.4	.	.	7.3	.	.	.	7.2	.	.	7.1
18.7 grams....	7.8	7.7	.	.	.	7.6	.	.	7.5	.	.	7.4	.	.	.	7.3	.	.	7.2	.	.
18.8 grams....	7.8	.	.	7.7	.	.	7.6	.	.	7.5	.	.	.	7.4	.	.	7.3	.	.	7.2	.
18.9 grams....	7.9	7.8	.	.	7.7	.	.	7.6	.	.	.	7.5	.	.	7.4	.	.	7.3	.	.	.
19.0 grams....	7.9	.	7.8	.	.	7.7	.	.	.	7.6	.	.	7.5	.	.	7.4	.	.	.	7.3	.
19.1 grams....	7.9	.	.	.	7.8	.	.	7.7	.	.	7.6	.	.	7.5	.	.	.	7.4	.	.	7.3
19.2 grams....	8.0	.	7.9	.	.	7.8	.	.	7.7	.	.	7.6	.	.	7.5	.	.	.	7.4	.	.
19.3 grams....	8.0	.	.	7.9	.	.	7.8	.	.	7.7	.	.	7.6	.	.	.	7.5	.	.	7.4	.
19.4 grams....	8.1	8.0	.	.	7.9	.	.	7.8	.	.	.	7.7	.	.	7.6	.	.	7.5	.	.	.
19.5 grams....	8.1	.	8.0	.	.	7.9	.	.	.	7.8	.	.	7.7	.	.	7.6	.	.	7.5	.	.
19.6 grams....	8.2	8.1	.	.	8.0	.	.	7.9	.	.	7.8	.	.	7.7	.	.	7.6	.	.	.	7.5
19.7 grams....	8.2	.	8.1	.	.	8.0	.	.	7.9	.	.	7.8	.	.	7.7	.	.	.	7.6	.	.
19.8 grams....	8.2	.	.	8.1	.	.	8.0	.	.	7.9	.	.	7.8	.	.	.	7.7	.	.	7.6	.
19.9 grams....	8.3	8.2	.	.	8.1	.	.	8.0	.	.	.	7.9	.	.	7.8	.	.	7.7	.	.	7.6
20.0 grams....	8.3	.	.	8.2	.	.	8.1	.	.	8.0	.	.	7.9	.	.	7.8	.	.	7.7	.	.

TABLE I.—*Equivalent percentage of a sample of grain, etc., when the weight of the sample analyzed and the weight of the mechanical separation are given*—Continued.

Weight of separation.	Weight of sample analyzed (grams).																				
	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
20.1 grams	8.4	8.3	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.7
20.2 grams	8.4	.	8.3	.	.	8.2	.	.	8.1	.	.	8.0	.	.	7.9	.	.	7.8	.	.	.
20.3 grams	8.4	.	.	8.3	.	.	8.2	.	.	8.1	.	.	8.0	.	.	.	7.9	.	.	7.8	.
20.4 grams	8.5	.	8.4	.	.	8.3	.	8.2	.	.	.	8.1	.	.	8.0	.	.	7.9	.	.	7.8
20.5 grams	8.5	.	.	8.4	.	.	8.3	.	.	8.2	.	.	8.1	.	.	8.0	.	.	7.9	.	.
20.6 grams	8.6	8.5	.	.	8.4	.	.	8.3	.	.	8.2	.	.	8.1	.	.	8.0	.	.	7.9	.
20.7 grams	8.6	.	8.5	.	.	8.4	.	.	8.3	.	.	8.2	.	.	8.1	.	.	8.0	.	.	.
20.8 grams	8.7	8.6	.	8.5	.	.	8.4	.	.	8.3	.	.	8.2	.	.	8.1	.	.	.	8.0	.
20.9 grams	8.7	.	8.6	.	.	8.5	.	.	8.4	.	.	8.3	.	.	8.2	.	.	8.1	.	.	8.0
21.0 grams	8.7	.	.	8.6	.	.	8.5	.	.	8.4	.	.	8.3	.	.	8.2	.	.	8.1	.	.
21.1 grams	8.8	8.7	.	.	8.6	.	.	8.5	.	.	8.4	.	.	8.3	.	.	8.2	.	.	8.1	.
21.2 grams	8.8	.	.	8.7	.	8.6	.	.	8.5	.	.	8.4	.	.	8.3	.	.	8.2	.	.	8.1
21.3 grams	8.9	8.8	.	.	8.7	.	8.6	.	.	8.5	.	.	8.4	.	.	8.3	.	.	8.2	.	.
21.4 grams	8.9	.	8.8	.	.	8.7	.	.	8.6	.	.	8.5	.	8.4	.	.	8.3	.	.	.	8.2
21.5 grams	8.9	.	.	8.8	.	.	8.7	.	.	8.6	.	.	8.5	.	.	8.4	.	.	8.3	.	.
21.6 grams	9.0	.	8.9	.	8.8	.	.	8.7	.	.	8.6	.	.	8.5	.	.	8.4	.	.	8.3	.
21.7 grams	9.0	.	.	8.9	.	.	8.8	.	8.7	.	.	8.6	.	.	8.5	.	.	8.4	.	.	8.3
21.8 grams	9.1	9.0	.	.	8.9	.	.	8.8	.	8.7	.	.	8.6	.	.	8.5	.	.	8.4	.	.
21.9 grams	9.1	.	9.0	.	.	8.9	.	.	8.8	.	.	8.7	.	8.6	.	.	8.5	.	.	8.4	.
22.0 grams	9.2	9.1	.	9.0	.	.	8.9	.	.	8.8	.	.	8.7	.	.	8.6	.	.	8.5	.	.
22.1 grams	9.2	.	9.1	.	9.0	.	.	8.9	.	.	8.8	.	.	8.7	.	.	8.6	.	.	8.5	.
22.2 grams	9.2	.	.	9.1	.	.	9.0	.	8.9	.	.	8.8	.	.	8.7	.	.	8.6	.	.	8.5
22.3 grams	9.3	9.2	.	.	9.1	.	.	9.0	.	8.9	.	.	8.8	.	.	8.7	.	.	8.6	.	.
22.4 grams	9.3	.	9.2	.	.	9.1	.	.	9.0	.	.	8.9	.	8.8	.	.	8.7	.	.	8.6	.

22.5 grams....	9.4	9.3	.	9.2	.	.	9.1	.	.	9.0	.	.	8.9	.	8.8	.	.	8.7	.	.	8.6
22.6 grams....	9.4	.	9.3	.	.	9.2	.	9.1	.	.	9.0	.	.	8.9	.	.	8.8	.	8.7	.	.
22.7 grams....	9.4	.	.	9.3	.	.	9.2	.	9.1	.	.	9.0	.	.	8.9	.	.	8.8	.	.	8.7
22.8 grams....	9.5	.	9.4	.	9.3	.	.	9.2	.	9.1	.	.	9.0	.	.	8.9	.	.	8.8	.	.
22.9 grams....	9.5	.	.	9.4	.	9.3	.	.	9.2	.	.	9.1	.	9.0	.	.	8.9	.	.	8.8	.
23.0 grams....	9.6	9.5	.	.	9.4	.	9.3	.	.	9.2	.	.	9.1	.	9.0	.	.	8.9	.	.	8.8
23.1 grams....	9.6	.	9.5	.	.	9.4	.	9.3	.	.	9.2	.	.	9.1	.	9.0	.	.	8.9	.	.
23.2 grams....	9.7	9.6	.	9.5	.	.	9.4	.	9.3	.	.	9.2	.	.	9.1	.	.	9.0	.	8.9	.
23.3 grams....	9.7	.	9.6	.	9.5	.	.	9.4	.	9.3	.	.	9.2	.	.	9.1	.	.	9.0	.	.
23.4 grams....	9.7	.	.	9.6	.	9.5	.	.	9.4	.	.	9.3	.	9.2	.	.	9.1	.	.	9.0	.
23.5 grams....	9.8	9.7	.	.	9.6	.	9.5	.	.	9.4	.	.	9.3	.	9.2	.	.	9.1	.	.	9.0
23.6 grams....	9.8	.	9.7	.	.	9.6	.	9.5	.	.	9.4	.	.	9.3	.	9.2	.	.	9.1	.	.
23.7 grams....	9.9	9.8	.	9.7	.	.	9.6	.	9.5	.	.	9.4	.	.	9.3	.	9.2	.	.	9.1	.
23.8 grams....	9.9	.	9.8	.	9.7	.	.	9.6	.	9.5	.	.	9.4	.	.	9.3	.	.	9.2	.	9.1
23.9 grams....	9.9	.	.	9.8	.	9.7	.	.	9.6	.	.	9.5	.	9.4	.	.	9.3	.	.	9.2	.
24.0 grams....	10.0	9.9	.	.	9.8	.	9.7	.	.	9.6	.	.	9.5	.	9.4	.	.	9.3	.	.	9.2
24.1 grams....	10.0	.	9.9	.	.	9.8	.	9.7	.	.	9.6	.	.	9.5	.	9.4	.	.	9.3	.	.
24.2 grams....	10.1	10.0	.	9.9	.	.	9.8	.	9.7	.	.	9.6	.	.	9.5	.	9.4	.	.	9.3	.
24.3 grams....	10.1	.	10.0	.	9.9	.	.	9.8	.	9.7	.	.	9.6	.	.	9.5	.	9.4	.	.	9.3
24.4 grams....	10.2	10.1	.	10.0	.	9.9	.	.	9.8	.	.	9.7	.	9.6	.	.	9.5	.	9.4	.	.
24.5 grams....	10.2	.	10.1	.	10.0	.	9.9	.	.	9.8	.	.	9.7	.	9.6	.	.	9.5	.	9.4	.
24.6 grams....	10.2	.	.	10.1	.	10.0	.	9.9	.	.	9.8	.	.	9.7	.	9.6	.	.	9.5	.	.
24.7 grams....	10.3	10.2	.	.	10.1	.	10.0	.	9.9	.	.	9.8	.	.	9.7	.	9.6	.	.	9.5	.
24.8 grams....	10.3	.	10.2	.	.	10.1	.	10.0	.	9.9	.	.	9.8	.	.	9.7	.	9.6	.	.	9.5
24.9 grams....	10.4	10.3	.	10.2	.	.	10.1	.	10.0	.	.	9.9	.	9.8	.	.	9.7	.	9.6	.	.
25.0 grams....	10.4	.	10.3	.	10.2	.	.	10.1	.	10.0	.	.	9.9	.	9.8	.	.	9.7	.	9.6	.

TABLE I.—*Equivalent percentage of a sample of grain, etc., when the weight of the sample analyzed and the weight of the mechanical separation are given*—Continued.

Weight of separation.	Weight of sample analyzed (grams).																				
	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
25.1 grams....	10.4	10.4	10.4	10.3	10.3	10.2	10.2	10.2	10.1	10.1	10.0	10.0	10.0	9.9	9.9	9.8	9.8	9.8	9.7	9.7	9.6
25.2 grams....	10.5	10.4	.	.	10.3	.	10.2	.	.	10.1	.	10.0	.	.	9.9	.	9.8	.	.	9.7	.
25.3 grams....	10.5	.	10.4	.	.	10.3	.	10.2	.	.	10.1	.	10.0	.	.	9.9	.	9.8	.	.	9.7
25.4 grams....	10.6	10.5	.	10.4	.	.	10.3	.	10.2	.	.	10.1	.	10.0	.	.	9.9	.	9.8	.	.
25.5 grams....	10.6	.	10.5	.	10.4	.	.	10.3	.	10.2	.	10.1	.	.	10.0	.	.	9.9	.	9.8	.
25.6 grams....	10.7	10.6	.	10.5	.	10.4	.	.	10.3	.	10.2	.	10.1	.	.	10.0	.	.	9.9	.	9.8
25.7 grams....	10.7	.	10.6	.	10.5	.	10.4	.	.	10.3	.	10.2	.	10.1	.	.	10.0	.	.	9.9	.
25.8 grams....	10.7	.	.	10.6	.	10.5	.	10.4	.	.	10.3	.	10.2	.	10.1	.	.	10.0	.	.	9.9
25.9 grams....	10.8	10.7	.	10.6	.	.	10.5	.	10.4	.	.	10.3	.	10.2	.	10.1	.	.	10.0	.	.
26.0 grams....	10.8	.	10.7	.	10.6	.	.	10.5	.	10.4	.	10.3	.	.	10.2	.	10.1	.	.	10.0	.
26.1 grams....	10.9	10.8	.	10.7	.	10.6	.	.	10.5	.	10.4	.	10.3	.	.	10.2	.	10.1	.	.	10.0
26.2 grams....	10.9	.	10.8	.	10.7	.	10.6	.	.	10.5	.	10.4	.	10.3	.	.	10.2	.	10.1	.	.
26.3 grams....	10.9	.	.	10.8	.	10.7	.	10.6	.	.	10.5	.	10.4	.	10.3	.	.	10.2	.	10.1	.
26.4 grams....	11.0	10.9	.	.	10.8	.	10.7	.	10.6	.	.	10.5	.	10.4	.	10.3	.	.	10.2	.	10.1
26.5 grams....	11.0	.	10.9	.	.	10.8	.	10.7	.	10.6	.	10.5	.	.	10.4	.	10.3	.	.	10.2	.
26.6 grams....	11.1	11.0	.	10.9	.	10.8	.	.	10.7	.	10.6	.	10.5	.	.	10.4	.	10.3	.	.	10.2
26.7 grams....	11.1	.	11.0	.	10.9	.	10.8	.	.	10.7	.	10.6	.	10.5	.	.	10.4	.	10.3	.	.
26.8 grams....	11.2	11.1	.	11.0	.	10.9	.	10.8	.	.	10.7	.	10.6	.	10.5	.	.	10.4	.	10.3	.
26.9 grams....	11.2	.	11.1	.	11.0	.	10.9	.	10.8	.	.	10.7	.	10.6	.	10.5	.	.	10.4	.	10.3
27.0 grams....	11.2	.	11.1	.	.	11.0	.	10.9	.	10.8	.	10.7	.	.	10.6	.	10.5	.	.	10.4	.
27.1 grams....	11.3	11.2	.	11.1	.	.	11.0	.	10.9	.	10.8	.	10.7	.	.	10.6	.	10.5	.	.	10.4
27.2 grams....	11.3	.	11.2	.	11.1	.	11.0	.	.	10.9	.	10.8	.	10.7	.	.	10.6	.	10.5	.	.
27.3 grams....	11.4	11.3	.	11.2	.	11.1	.	11.0	.	.	10.9	.	10.8	.	10.7	.	.	10.6	.	10.5	.
27.4 grams....	11.4	.	11.3	.	11.2	.	11.1	.	11.0	.	.	10.9	.	10.8	.	10.7	.	.	10.6	.	10.5

27.5 grams....	11.4	.	.	11.3	.	11.2	.	11.1	.	11.0	.	10.9	.	.	10.8	.	10.7	.	10.6	.	.
27.6 grams....	11.5	11.4	.	11.3	.	.	11.2	.	11.1	.	11.0	.	10.9	.	.	10.8	.	10.7	.	10.6	.
27.7 grams....	11.5	.	11.4	.	11.3	.	.	11.2	.	11.1	.	11.0	.	10.9	.	.	10.8	.	10.7	.	10.6
27.8 grams....	11.6	11.5	.	11.4	.	11.3	.	11.2	.	.	11.1	.	11.0	.	10.9	.	10.8	.	.	10.7	.
27.9 grams....	11.6	.	11.5	.	11.4	.	11.3	.	11.2	.	.	11.1	.	11.0	.	10.9	.	10.8	.	.	10.7
28.0 grams....	11.7	11.6	.	11.5	.	11.4	.	11.3	.	11.2	.	11.1	.	.	11.0	.	10.9	.	10.8	.	.
28.1 grams....	11.7	11.6	.	.	11.5	.	11.4	.	11.3	.	11.2	.	11.1	.	.	11.0	.	10.9	.	10.8	.
28.2 grams....	11.7	.	11.6	.	11.5	.	.	11.4	.	11.3	.	11.2	.	11.1	.	11.0	.	.	10.9	.	10.8
28.3 grams....	11.8	11.7	.	11.6	.	11.5	.	11.4	.	.	11.3	.	11.2	.	11.1	.	11.0	.	.	10.9	.
28.4 grams....	11.8	.	11.7	.	11.6	.	11.5	.	11.4	.	.	11.3	.	11.2	.	11.1	.	11.0	.	.	10.9
28.5 grams....	11.9	11.8	.	11.7	.	11.6	.	11.5	.	11.4	.	11.3	.	.	11.2	.	11.1	.	11.0	.	.
28.6 grams....	11.9	.	11.8	.	11.7	.	11.6	.	11.5	.	11.4	.	11.3	.	11.2	.	.	11.1	.	11.0	.
28.7 grams....	11.9	.	11.8	.	.	11.7	.	11.6	.	11.5	.	11.4	.	11.3	.	11.2	.	.	11.1	.	11.0
28.8 grams....	12.0	11.9	.	11.8	.	11.7	.	11.6	.	.	11.5	.	11.4	.	11.3	.	11.2	.	.	11.1	.
28.9 grams....	12.0	.	11.9	.	11.8	.	11.7	.	11.6	.	.	11.5	.	11.4	.	11.3	.	11.2	.	11.1	.
29.0 grams....	12.1	12.0	.	11.9	.	11.8	.	11.7	.	11.6	.	11.5	.	.	11.4	.	11.3	.	11.2	.	11.1
29.1 grams....	12.1	.	12.0	.	11.9	.	11.8	.	11.7	.	11.6	.	11.5	.	11.4	.	.	11.3	.	11.2	.
29.2 grams....	12.2	12.1	.	12.0	.	11.9	.	11.8	.	11.7	.	11.6	.	11.5	.	11.4	.	.	11.3	.	11.2
29.3 grams....	12.2	12.1	.	12.0	.	11.9	.	.	11.8	.	11.7	.	11.6	.	11.5	.	11.4	.	11.3	.	.
29.4 grams....	12.2	.	12.1	.	12.0	.	11.9	.	11.8	.	.	11.7	.	11.6	.	11.5	.	11.4	.	11.3	.
29.5 grams....	12.3	12.2	.	12.1	.	12.0	.	11.9	.	11.8	.	11.7	.	.	11.6	.	11.5	.	11.4	.	11.3
29.6 grams....	12.3	.	12.2	.	12.1	.	12.0	.	11.9	.	11.8	.	11.7	.	11.6	.	.	11.5	.	11.4	.
29.7 grams....	12.4	12.3	.	12.2	.	12.1	.	12.0	.	11.9	.	11.8	.	11.7	.	11.6	.	11.5	.	.	11.4
29.8 grams....	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.	11.9	.	11.8	.	11.7	.	11.6	.	11.5	.	.
29.9 grams....	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.	.	11.9	.	11.8	.	11.7	.	11.6	.	11.5	.
30.0 grams....	12.5	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.	11.9	.	11.8	.	.	11.7	.	11.6	.	11.5

TABLE I.—*Equivalent percentage of a sample of grain, etc., when the weight of the sample analyzed and the weight of the mechanical separation are given*—Continued.

Weight of separation.	Weight of sample analyzed (grams).																				
	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
30.1 grams....	12.5	12.5	12.4	12.4	12.3	12.3	12.2	12.2	12.1	12.1	12.0	12.0	11.9	11.9	11.8	11.8	11.7	11.7	11.7	11.6	11.6
30.2 grams....	12.6	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.	11.9	.	11.8	.	11.7	.	.	11.6
30.3 grams....	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.	11.9	.	11.8	.	11.7	.	11.6
30.4 grams....	12.7	12.6	.	12.5	12.4	.	12.3	.	12.2	.	.	12.1	.	12.0	.	11.9	.	11.8	.	11.7	.
30.5 grams....	12.7	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.	.	11.9	.	11.8	.	11.7
30.6 grams....	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.	11.9	.	.	11.8	.
30.7 grams....	12.8	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.	11.9	.	11.8	.
30.8 grams....	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.	11.9	.	11.8
30.9 grams....	12.9	12.8	.	12.7	.	12.6	.	12.5	12.4	.	.	12.3	.	12.2	.	12.1	.	12.0	.	11.9	.
31.0 grams....	12.9	.	12.8	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.	.	12.0	.	11.9
31.1 grams....	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.	.
31.2 grams....	13.0	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.	12.0	.
31.3 grams....	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.	12.0
31.4 grams....	13.1	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1	.
31.5 grams....	13.1	.	13.0	.	12.9	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	.	12.1
31.6 grams....	13.2	13.1	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.	12.1
31.7 grams....	13.2	13.1	.	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2	.
31.8 grams....	13.2	.	13.1	.	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.	12.2
31.9 grams....	13.3	13.2	.	13.1	.	13.0	.	12.9	.	12.8	.	12.7	12.6	.	12.5	.	.	12.4	.	12.3	.
32.0 grams....	13.3	.	13.2	.	13.1	.	13.0	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3	.
32.1 grams....	13.4	13.3	.	13.2	13.1	.	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.	12.3
32.2 grams....	13.4	.	13.3	13.2	.	13.1	.	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4	.
32.3 grams....	13.4	.	13.3	.	13.2	.	13.1	.	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.	12.4
32.4 grams....	13.5	13.4	.	13.3	.	13.2	.	13.1	.	13.0	.	12.9	12.8	.	12.7	.	12.6	.	12.5	.	.

32.5 grams....	13.5	.	13.4	.	13.3	.	13.2	13.1	.	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.	12.5	.
32.6 grams....	13.6	13.5	.	13.4	.	13.3	13.2	.	13.1	.	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.	12.5
32.7 grams....	13.6	.	13.5	13.4	.	13.3	.	13.2	.	13.1	.	13.0	.	12.9	.	12.8	.	12.7	.	12.6	.
32.8 grams....	13.7	13.6	13.5	.	13.4	.	13.3	.	13.2	.	13.1	.	13.0	.	12.9	.	12.8	.	12.7	.	12.6
32.9 grams....	13.7	13.6	.	13.5	.	13.4	.	13.3	.	13.2	.	13.1	13.0	.	12.9	.	12.8	.	12.7	.	12.6
33.0 grams....	13.7	.	13.6	.	13.5	.	13.4	.	13.3	13.2	.	13.1	.	13.0	.	12.9	.	12.8	.	12.7	.
33.1 grams....	13.8	13.7	.	13.6	.	13.5	13.4	.	13.3	.	13.2	.	13.1	.	13.0	.	12.9	.	12.8	.	12.7
33.2 grams....	13.8	.	13.7	.	13.6	13.5	.	13.4	.	13.3	.	13.2	.	13.1	.	13.0	.	12.9	.	12.8	.
33.3 grams....	13.9	13.8	.	13.7	13.6	.	13.5	.	13.4	.	13.3	.	13.2	.	13.1	13.0	.	12.9	.	12.8	.
33.4 grams....	13.9	13.8	.	13.7	.	13.6	.	13.5	.	13.4	.	13.3	13.2	.	13.1	.	13.0	.	12.9	.	12.8
33.5 grams....	13.9	.	13.8	.	13.7	.	13.6	.	13.5	13.4	.	13.3	.	13.2	.	13.1	.	13.0	.	12.9	.
33.6 grams....	14.0	13.9	.	13.8	.	13.7	13.6	.	13.5	.	13.4	.	13.3	.	13.2	.	13.1	.	13.0	.	12.9
33.7 grams....	14.0	.	13.9	.	13.8	13.7	.	13.6	.	13.5	.	13.4	.	13.3	.	13.2	.	13.1	.	13.0	.
33.8 grams....	14.1	14.0	.	13.9	13.8	.	13.7	.	13.6	.	13.5	.	13.4	13.3	.	13.2	.	13.1	.	13.0	.
33.9 grams....	14.1	.	14.0	13.9	.	13.8	.	13.7	.	13.6	.	13.5	13.4	.	13.3	.	13.2	.	13.1	.	13.0
34.0 grams....	14.2	14.1	14.0	.	13.9	.	13.8	.	13.7	13.6	.	13.5	.	13.4	.	13.3	.	13.2	.	13.1	.
34.1 grams....	14.2	14.1	.	14.0	.	13.9	.	13.8	13.7	.	13.6	.	13.5	.	13.4	.	13.3	.	13.2	.	13.1
34.2 grams....	14.2	.	14.1	.	14.0	13.9	.	13.8	.	13.7	.	13.6	.	13.5	.	13.4	.	.	13.2	.	13.1
34.3 grams....	14.3	14.2	.	14.1	14.0	.	13.9	.	13.8	.	13.7	.	13.6	13.5	.	13.4	.	13.3	.	13.2	.
34.4 grams....	14.3	.	14.2	14.1	.	14.0	.	13.9	.	13.8	.	13.7	13.6	.	13.5	.	13.4	.	13.3	.	13.2
34.5 grams....	14.4	14.3	14.2	.	14.1	.	14.0	.	13.9	13.8	.	13.7	.	13.6	.	13.5	.	13.4	.	13.3	.
34.6 grams....	14.4	14.3	.	14.2	.	14.1	.	14.0	13.9	.	13.8	.	13.7	.	13.6	.	13.5	.	13.4	13.3	.
34.7 grams....	14.4	.	14.3	.	14.2	.	14.1	14.0	.	13.9	.	13.8	.	13.7	.	13.6	13.5	.	13.4	.	13.3
34.8 grams....	14.5	14.4	.	14.3	.	14.2	14.1	.	14.0	.	13.9	.	13.8	13.7	.	13.6	.	13.5	.	13.4	.
34.9 grams....	14.5	.	14.4	.	14.3	14.2	.	14.1	.	14.0	.	13.9	13.8	.	13.7	.	13.6	.	13.5	.	13.4
35.0 grams....	14.6	14.5	.	14.4	14.3	.	14.2	.	14.1	14.0	.	13.9	.	13.8	.	13.7	.	13.6	.	13.5	.

TABLE I.—*Equivalent percentage of a sample of grain, etc., when the weight of the sample analyzed and the weight of the mechanical separation are given*—Continued.

Weight of separation.	Weight of sample analyzed (grams).																				
	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
35.1 grams....	14.6	14.6	14.5	14.4	14.4	14.3	14.3	14.2	14.1	14.1	14.0	14.0	13.9	13.9	13.8	13.8	13.7	13.6	13.6	13.5	13.5
35.2 grams....	14.7	14.6	14.5	.	14.4	.	14.3	14.2	.	14.1	.	14.0	13.9	.	13.8	.	13.7	.	13.6	.	13.5
35.3 grams....	14.7	14.6	.	14.5	.	14.4	14.3	.	14.2	.	14.1	.	14.0	13.9	.	13.8	.	13.7	.	13.6	.
35.4 grams....	14.7	.	14.6	.	14.5	14.4	.	14.3	.	14.2	.	14.1	14.0	.	13.9	.	13.8	.	13.7	.	13.6
35.5 grams....	14.8	14.7	.	14.6	14.5	.	14.4	.	14.3	14.2	.	14.1	.	14.0	.	13.9	.	13.8	13.7	.	13.6
35.6 grams....	14.8	.	14.7	14.6	.	14.5	.	14.4	14.3	.	14.2	.	14.1	.	14.0	.	13.9	13.8	.	13.7	.
35.7 grams....	14.9	14.8	14.7	.	14.6	.	14.5	14.4	.	14.3	.	14.2	.	14.1	14.0	.	13.9	.	13.8	.	13.7
35.8 grams....	14.9	14.8	.	14.7	.	14.6	14.5	.	14.4	.	14.3	.	14.2	14.1	.	14.0	.	13.9	.	13.8	.
35.9 grams....	14.9	.	14.8	.	14.7	14.6	.	14.5	.	14.4	.	14.3	14.2	.	14.1	.	14.0	.	13.9	.	13.8
36.0 grams....	15.0	14.9	.	14.8	14.7	.	14.6	.	14.5	14.4	.	14.3	.	14.2	14.1	14.1	.	14.0	13.9	.	13.8
36.1 grams....	15.0	.	14.9	14.8	.	14.7	.	14.6	14.5	.	14.4	.	14.3	.	14.2	14.1	.	14.0	.	13.9	.
36.2 grams....	15.1	15.0	14.9	.	14.8	.	14.7	14.6	.	14.5	. .	14.4	.	14.3	14.2	.	14.1	.	14.0	.	13.9
36.3 grams....	15.1	.	15.0	14.9	.	14.8	14.7	.	14.6	.	14.5	.	14.4	14.3	.	14.2	.	14.1	.	14.0	.
36.4 grams....	15.2	15.1	15.0	.	14.9	14.8	.	14.7	.	14.6	.	14.5	14.4	.	14.3	.	14.2	.	14.1	14.0	.
36.5 grams....	15.2	15.1	.	15.0	14.9	.	14.8	.	14.7	14.6	.	14.5	.	14.4	.	14.3	14.2	.	14.1	.	14.0
36.6 grams....	15.2	.	15.1	.	15.0	14.9	.	14.8	14.7	.	14.6	.	14.5	.	14.4	14.3	.	14.2	.	14.1	.
36.7 grams....	15.3	15.2	.	15.1	15.0	.	14.9	14.8	.	14.7	.	14.6	.	14.5	14.4	.	14.3	.	14.2	.	14.1
36.8 grams....	15.3	.	15.2	15.1	.	15.0	14.9	.	14.8	.	14.7	.	14.6	14.5	.	14.4	.	14.3	.	14.2	14.1
36.9 grams....	15.4	15.3	15.2	.	15.1	.	15.0	14.9	.	14.8	.	14.7	14.6	.	14.5	.	14.4	14.3	.	14.2	.
37.0 grams....	15.4	15.3	.	15.2	.	15.1	15.0	.	14.9	14.8	.	14.7	.	14.6	.	14.5	14.4	.	14.3	.	14.2
37.1 grams....	15.4	.	15.3	.	15.2	15.1	.	15.0	14.9	.	14.8	.	14.7	.	14.6	14.5	.	14.4	.	14.3	.
37.2 grams....	15.5	15.4	.	15.3	15.2	.	15.1	.	15.0	14.9	.	14.8	.	14.7	14.6	.	14.5	.	14.4	.	14.3
37.3 grams....	15.5	.	15.4	15.3	.	15.2	.	15.1	15.0	.	14.9	.	14.8	14.7	.	14.6	.	14.5	14.4	.	14.3
37.4 grams....	15.6	15.5	15.4	.	15.3	.	15.2	15.1	.	15.0	.	14.9	14.8	.	14.7	.	14.6	14.5	.	14.4	.

37.5 grams....	15.6	.	15.5	15.4	.	15.3	15.2	.	15.1	.	15.0	11.9	.	14.8	.	14.7	14.6	.	14.5	.	14.4
37.6 grams....	15.7	15.6	15.5	.	15.4	15.3	.	15.2	.	15.1	15.0	.	14.9	.	14.8	14.7	.	14.6	.	14.5	.
37.7 grams....	15.7	15.6	.	15.5	15.4	.	15.3	.	15.2	15.1	.	15.0	.	11.9	14.8	.	14.7	.	14.6	11.5	.
37.8 grams....	15.7	.	15.6	15.5	.	15.4	15.3	.	15.2	.	15.1	15.0	.	14.9	.	14.8	.	14.7	14.6	.	11.5
37.9 grams....	15.8	15.7	.	15.6	15.5	.	15.4	15.3	.	15.2	.	15.1	15.0	.	14.9	.	14.8	14.7	.	14.6	.
38.0 grams....	15.8	.	15.7	15.6	.	15.5	15.4	.	15.3	.	15.2	15.1	.	15.0	.	14.9	11.8	.	11.7	.	14.6
38.1 grams....	15.9	15.8	15.7	.	15.6	15.5	.	15.4	15.3	15.3	15.2	.	15.1	15.0	.	14.9	.	14.8	.	14.7	14.6
38.2 grams....	15.9	15.8	.	15.7	15.6	.	15.5	.	15.4	15.3	.	15.2	15.1	.	15.0	.	14.9	.	14.8	14.7	.
38.3 grams....	15.9	.	15.8	.	15.7	15.6	.	15.5	15.4	.	15.3	15.2	.	15.1	.	15.0	.	14.9	14.8	.	14.7
38.4 grams....	16.0	15.9	.	15.8	15.7	.	15.6	15.5	.	15.4	.	15.3	15.2	.	15.1	15.0	.	14.9	.	14.8	.
38.5 grams....	16.0	.	15.9	15.8	.	15.7	15.6	.	15.5	.	15.4	15.3	.	15.2	15.1	.	15.0	.	14.9	.	14.8
38.6 grams....	16.1	16.0	15.9	.	15.8	15.7	.	15.6	.	15.5	15.4	.	15.3	15.2	.	15.1	.	.	15.0	14.9	14.8
38.7 grams....	16.1	16.0	.	15.9	.	15.8	15.7	.	15.6	15.5	.	15.4	15.3	.	15.2	.	15.1	15.0	.	14.9	.
38.8 grams....	16.2	16.1	16.0	.	15.9	15.8	.	15.7	15.6	.	15.5	15.4	.	15.3	.	15.2	15.1	.	15.0	.	14.9
38.9 grams....	16.2	16.1	.	16.0	15.9	.	15.8	15.7	.	15.6	.	15.5	15.4	.	15.3	15.2	.	15.1	.	15.0	.
39.0 grams....	16.2	.	16.1	16.0	.	15.9	15.8	.	15.7	.	15.6	15.5	.	15.4	15.3	.	15.2	.	15.1	15.0	.
39.1 grams....	16.3	16.2	16.1	.	16.0	15.9	.	15.8	.	15.7	15.6	.	15.5	15.4	.	15.3	.	15.2	15.1	.	15.0
39.2 grams....	16.3	.	16.2	16.1	.	16.0	15.9	.	15.8	15.7	.	15.6	15.5	.	15.4	.	15.3	15.2	.	15.1	.
39.3 grams....	16.4	16.3	16.2	.	16.1	16.0	.	15.9	15.8	.	15.7	15.6	.	15.5	.	15.4	15.3	.	15.2	.	15.1
39.4 grams....	16.4	16.3	.	16.2	16.1	.	16.0	15.9	.	15.8	.	15.7	15.6	.	15.5	15.4	.	15.3	.	15.2	15.1
39.5 grams....	16.4	.	16.3	16.2	.	16.1	16.0	.	15.9	.	15.8	15.7	.	15.6	15.5	.	15.4	.	15.3	15.2	.
39.6 grams....	16.5	16.4	.	16.3	16.2	.	16.1	16.0	.	15.9	15.8	.	15.7	15.6	.	15.5	.	15.4	15.3	.	15.2
39.7 grams....	16.5	.	16.4	16.3	.	16.2	16.1	.	16.0	15.9	.	15.8	15.7	.	15.6	.	15.5	15.4	.	15.3	.
39.8 grams....	16.6	16.5	16.4	.	16.3	16.2	.	16.1	16.0	.	15.9	15.8	.	15.7	.	15.6	15.5	.	15.4	.	15.3
39.9 grams....	16.6	16.5	.	16.4	16.3	.	16.2	16.1	.	16.0	.	15.9	15.8	.	15.7	15.6	.	15.5	.	15.4	15.3
40.0 grams....	16.7	16.6	16.5	.	16.4	16.3	.	16.2	16.1	.	16.0	15.9	.	15.8	15.7	.	15.6	.	15.5	15.4	.

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A. D. MELVIN, Chief

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AN INTRADERMAL TEST FOR BACTERIUM PULLORUM INFECTION IN FOWLS.

By Archibald R. Ward and Bernard A. Gallagher, *Pathological Division.*

CONTENTS.

DISSEMINATION OF INFECTION IN WHITE DIARRHEA.

Of the numerous diseases to which poultry are susceptible it is safe to say that bacillary white diarrhea is by far the most widespread and most destructive. Its ravages are confined principally to baby chicks, but it is the pullorum infection in the hen which is directly responsible for outbreaks of white diarrhea in the chicks, since a certain percentage of her eggs hatch infected chicks and the excretions of these spread the disease to the other birds in the brood. The exceedingly high mortality of white diarrhea, amounting in some cases to almost 100 per cent of the hatch, practically prevents the rearing of chicks in infected flocks. The disease is contracted during the first four days of life, and deaths occur as a rule during the first month. It has been demonstrated conclusively by several investigators that chicks which recover may carry the causative bacterium in the ovary and serve as a source of infection in the future. Infected hens usually exhibit an ovary containing several angular, hard, discolored ova; however, the organ may continue to functionate and from time to time an ovum is released which harbors the infective agent. Outbreaks of white diarrhea as a result of con-

Note.—This bulletin is a report on a study of a disease of fowls that is quite destructive, and should be serviceable to those who are interested in poultry and poultry diseases.

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taminated incubators or brooders could be controlled readily by sanitary measures, but infection through the egg must be prevented by a process of weeding out the carriers among the hens used for breeding.

THE AGGLUTINATION TEST.

Since the presence of the *Bacterium pullorum* in the ovary of the hen is not betrayed by external symptoms, it was necessary to devise a biologic method of diagnosis in order to detect the presence of the disease in the affected birds. The agglutination test was found to be applicable for this purpose, and several agricultural experiment stations have taken up the work on an extended scale, offering the service to poultrymen at a price that barely covers the cost of the work. This, in Connecticut, is understood to be 10 cents a fowl. The work of drawing blood samples and sending to a laboratory is necessarily tedious and relatively expensive as compared with the value of a bird. A simpler, cheaper, and equally accurate diagnostic method would undoubtedly contribute to greater popularity of this valuable work in disease prevention.

EXPERIMENTAL WORK.

The writers have undertaken to determine the possibility of preparing a biological product from *Bacterium pullorum* to be used for the diagnosis of the disease caused by that organism. The general idea was to develop a diagnostic method somewhat analogous to the intradermal tuberculin test, particularly as applied to fowls.

TEST OF ARTIFICIALLY INFECTED BIRDS.

Two strains of *Bacterium pullorum* were planted in 1,500 c. c. of plain bouillon in the amount of one loopful each. This culture was incubated at 37° C. from September 19 to October 19, 1914. It was then placed in the ice box until May 4, 1915. On this date 100 c. c. of the culture was passed through a Berkefeld filter. The filtrate was determined to be sterile by cultural tests. Carbolic acid was then added in sufficient quantity to make a 0.5 per cent solution.

On May 17, 1915, two drops of this filtrate were injected into the right wattle of a hen that had been injected with *Bacterium pullorum* on September 22, 1914. The liquid was injected slightly above the lower border of the wattle and no attempt was made to place it within the layers of skin. Twenty-four hours later the wattle showed an edematous swelling. The following day, 48 hours after injection, there was noted a pronounced edematous infiltration of the entire wattle. A swelling of this size in other intradermal tests would be considered as positive. The temperature was normal. On May 20 the swelling of the wattle decreased considerably, and 90 hours after injection the wattle appeared normal. The wattle of a control, a noninfected bird, injected at the same time, remained normal. On autopsy the ovary of the infected bird presented several angular ova typical of pullorum infection. A pure culture of *B. pullorum* was isolated from the ovary. The result of this experiment suggested that a diagnostic test might be developed.

Work with the same filtrate was continued by evaporating 100 c. c. to one-tenth of its volume in a water bath at the boiling point, the purpose being to test the value of a culture filtrate containing the products of the organism in a more concentrated form.

Twelve fowls were injected intravenously on May 27, 1915, with 1.5 c. c. each of a 48-hour bouillon culture of six strains of *B. pullorum*. About two days after inoculation the fowls showed marked symptoms of illness—pale comb, drowsy attitude, and ruffled feathers. Five of this lot died within a period of 26 days as a result of the injection. On autopsy the following lesions were observed: Livers enlarged, darker than normal, and covered with necrotic foci. Spleens were enlarged and studded with necrotic foci. Ovaries contained irregular-shaped hard, dark-colored ova typical of pullorum infection. In one case there was severe pericarditis and in another considerable amber-colored fluid in the peritoneal cavity.

On June 9, thirteen days after the fowls were inoculated and while they still were sick, blood was drawn for serum tests. Of these, fowl 73 was injected in the right wattle with 0.1 c. c. of the concentrated filtrate. Three hours after injection considerable edema of the wattle was observed.

Two control fowls, 74 and 75, supposedly healthy birds, each received 0.1 c. c. of the concentrated filterate in the right wattle. Three hours later they showed edema of the wattle, practically of the same extent as that shown by the infected bird.

On the next day the swelling of the wattle of the control fowls 74 and 75 had entirely disappeared, while fowl 73 showed considerable swelling. This swelling continued to be marked at the forty-eighth hour, after which it began to subside.

The results of this test are shown in Table I and include the results of autopsy, cultural, and agglutination tests.

TABLE I.—*Concentrated filtrate tested on fowls 13 days after inoculation.*

Fowl No.—	Edema after 3 hours, June 9.	Edema after 24 hours, June 10.	Edema after 48 hours, June 11.	Autopsy.	Culture.	Agglutination, 1 : 100.
73	+	+	+	+	+	+
74 [1]	+	−	−	−	−	−
75 [1]	+	−	−	−	−	−

[1] Controls.

In this second test, while the concentrated filtrate gave satisfactory results, the reaction was not as marked as in the case of the first fowl, on which the nonconcentrated fluid was used.

On June 22 a third series of trials with the filtrate was conducted upon 6 fowls that had been inoculated intravenously on May 27 with a culture of *Bacterium pullorum*.

Fowls 77, 78, and 81, with two controls, 86 and 87, received in the right wattle 0.1 c. c. of the same concentrated filtrate as used before. In each case the injected wattles showed some edema within an hour.

On June 24 fowls 77 and 87 still showed slight edema, while fowl 81 showed a considerable swelling. The results of these tests are shown in Table II, together with data on agglutination test, autopsy, and cultures from ovaries made at a later date.

TABLE II.—*Concentrated filtrate tested on fowls 26 days after inoculation.*

Fowl No.—	Edema after 1 hour, June 22.	Edema after 24 hours, June 23.	Edema after 48 hours, June 24.	Autopsy.	Culture.	Agglutination, 1 : 100.
77	Slight	Slight	Slight	+	+	+
78	do	—	—	+	+	+
81	do	Slight	+	?	+	+
86 [1]	do	—	—	—	—	—
87 [1]	do	Slight	Slight	0	0	0

[1] Controls.

At the same time that the foregoing test was made a similar one was conducted with the original nonconcentrated filtrate.

Infected fowls 76, 79, and 82, together with fowls 88 and 89, supposedly noninfected controls, were injected in the right wattle with 0.1 c. c. of nonconcentrated filtrate. All showed a discernible edema shortly after injection.

On June 23 a slight edema persisted in fowls 76, 79, 82, and 88 (control). On June 24 fowl 88, the control, still showed a slight edema, fowl 76 showed a slight reaction, while fowls 79 and 82 showed swelling indicative of a fair positive reaction. The results of these tests and other data are given in Table III.

TABLE III.—*Nonconcentrated filtrate tested on fowls 26 days after inoculation.*

Fowl No.—	Edema after 1 hour, June 22.	Edema after 24 hours, June 23.	Edema after 48 hours, June 24.	Autopsy.	Culture.	Agglutination, 1:100.
76	Slight.	Slight.	Slight.	+	+	+
79	Slight.	Slight.	+	+	+	+
82	Slight.	Slight.	+	?	+	+
88 [1]	Slight.	Slight.	Slight.	+	+	+
89 [1]	Slight.	—	—	—	—	—

[1] Controls.

Comparing the results shown in Tables II and III, it would appear that the nonconcentrated filtrate has up to date given the most satisfactory results.

On August 16, 1915, tests of the original nonconcentrated filtrate were made. Fowls 73, 76, 77, 78, 79, 81, and 82 were injected with 0.1 c. c. in the left wattle. Of these, fowls 73, 81, and 82 showed reactions at 48 hours. These had reacted previously, fowl 73 on June 9, and the other two on June 22.

Fowls 76, 77, and 78 did not react from the injection on August 16, and it is noted that they had not reacted well from the injection on June 22. At that time fowl 78 was negative and fowls 76 and 77 were rated as slight. Of four controls, fowls 95, 96, 97, and 98, injected with filtrate on August 16, one, fowl 95, gave a reaction.

Table IV shows the present test, together with previous and subsequent tests on these birds. For convenience the table includes the results of two succeeding tests on some of these birds, together with the results of the agglutination test, autopsy, and cultures from ovaries made at a later date.

TABLE IV.—*Retests of fowls with various test products.*

Fowl No.—	Concentrated filtrate.		Nonconcentrated filtrate.		Concentrated filtrate.		Nonconcentrated filtrate.		Dead culture.				Autopsy.	Culture from ovary.	Agglutination, 1 : 100.
	June.		June.		June.		Aug.		Sept.						
	10	11	23	24	23	24	17	18	3	4	21	22			
73	+	+	....	....	....	....	+	+	+	+	+	+	+	+	+
76	....	....	Slight.	Slight.	....	....	−	−	....	....	....	....	+	+	+
77	....	....	....	....	Slight.	Slight.	−	−	Slight.	Slight.	Slight.	Slight.	+	+	+
78	....	....	....	....	−	−	−	−	....	....	+	Slight.	+	+	+
79	....	....	Slight.	+	....	....	−	−	....	....	+	+	+	+	+
81	....	....	....	....	Slight.	+	+	+	....	....	+	+	?	−	+
82	....	....	Slight.	+	....	....	+	+	....	....	+	Slight.	?	−	+
95[1]	....	....	....	....	....	....	+	+	....	....	....	....	+	+	+
96[1]	....	....	....	....	....	....	−	−	....	....	....	....	−	−	−
97[1]	....	....	....	....	....	....	−	−	....	....	....	....	−	−	−
98[1]	....	....	....	....	....	....	−	−	....	....	....	....	−	−	−

[1] Controls.

The fact as shown in the tables that three controls, fowls 87, 88, and 95, gave slight reactions, suggested the idea that an edema persisting for 24 hours or longer after injection might possibly be induced by causes such as irritation from the carbolic acid in the test fluid or puncture by the hypodermic needle. In order to determine this point, 6 fowls were tested, as follows: Two were injected in the wattle with 0.1 c. c. of plain bouillon, 2 with 0.1 c. c. of boullion carbolized to the same degree as the culture filtrate, and 2 received the hypodermic-needle puncture only. No reaction occurred as a result, and there remained the alternative conclusion that the test was either nonspecific or that the reacting controls were infected. Some of the control birds had been secured in the open market, and nothing was known of their previous exposure. Unfortunately control fowl 87, which showed a slight reaction on June 23, died from intercurrent causes and in the absence of the authors was not autopsied. As appears in autopsy notes later, control fowls 88 and 95, which also had reacted, were found to be infected birds.

On August 25 fowls 76, 95, and 96 and a control supposedly negative were killed by bleeding and samples held for agglutination tests. The ovary of fowl 76 contained angular ova typical of pullorum infection, that of fowl 96 dried encapsulated ovum and cysts, not certainly due to pullorum infection, and that of fowl 95 one or two angular ova and two large cysts.

Cultures were made from ovaries of fowls 76 and 95 which yielded growths characteristic of *Bacterium pullorum*, while that from fowl 96 yielded a heavy growth not resembling that of *Bacterium pullorum*. Fowl 76 gave positive agglutination in 0.01 dilution; fowl 95 in 0.002 dilution, while fowl 96 was negative at 0.04 dilution.

An antigen was made from the culture obtained from fowl 96 and tested against the serum of fowl 76, but gave a negative agglutination at 0.04. The result further strengthens the conclusion that the infection in the ovary of fowl 96 was not due to *Bacterium pullorum*. A check was run on the serum of fowl 76 with *Bacillus abortus* as an antigen, with no agglutination resulting. It is seen that fowl 76, although it did not react well to the intradermal test, gave an agglutination of 1:100. Also, fowl 95 was undoubtedly infected with *Bacterium pullorum*.

With a view of securing a diagnostic agent that would increase the size of the swelling in the wattle, the writers next tried a product consisting of six strains of *B. pullorum* which had been grown in plain bouillon at a temperature of 37.5° C. for one month. The culture was killed by heating at 60° C. for one hour in a water bath and then carbolized to 0.5 per cent. The organisms were not removed from the medium, and this product was employed in all subsequent tests.

TABLE V.—*Tests with killed bouillon cultures.*

Fowl No.—	Edema after 3 hours, Sept. 2.	Edema after 24 hours, Sept. 3.	Edema after 48 hours, Sept. 4.	Autopsy.	Culture from ovary.	Agglutination, 1:100.
73	Marked	Marked positive	Positive	+	+	+
77	Considerable	Slight	Trace	+	+	+
186[1]	Slight	—	—	0	0	0

[1] Control.

On September 2, fowls 73 and 77 and control fowl 186 were injected with 0.1 c. c. As shown in Table V edema was present at 24 hours in fowls 73 and 77 and entirely absent in control fowl 186.

On September 20 the following birds were injected in the wattle with 0.1 c. c. of the same bacterial product as used in the preceding test: Fowls 73, 77, 78, 79, 81, 82, and controls 55, 74, 88, 89, 90, 92, 97, 98, and 99. The results of the test are shown in Table VI.

TABLE VI.—*Further tests with killed bouillon cultures.*

Fowl No.—	Edema after 24 hours, Sept. 21.	Edema after 48 hours, Sept. 22.	Autopsy.	Culture.	Agglutination, 1:100.
73	+	+	+	+	+
77	Slight	Slight	+	+	+
78	+	do	+	+	+
79	+	+	+	+	+
81	+	+	?	+	+
82	+	Slight	?	–	+
55[1]	–	–	0	0	Not tested.
74[1]	–	–	–	–	–
88[1]	+	Slight	+	+	+
89[1]	–	–	–	–	–
90[1]	–	–	0	0	Not tested.
92[1]	–	–	0	0	Do.
99[1]	+	–	–	–	–

[1] Controls.

On September 23, the following fowls were killed by bleeding and blood was saved for agglutination tests. Autopsy notes follow:

Fowl 73. A hard tumorlike mass about an inch in diameter is attached to the ovary by fibrous threads and vessels. Other small ova show typical appearance of pullorum infection. *Bacterium pullorum* was recovered in pure culture from the ovary.

Fowl 77. Ovary contains one ovum the size of a pea, having the appearance of an old pullorum ovum. *B. pullorum* was obtained in pure culture.

Fowl 78. One ovum the size of a pea and having characteristic color of those with pullorum infection. Also several smaller similar ones and a cyst the size of a hickory nut which is filled with a colorless fluid. *B. pullorum* was obtained in pure culture from the ovum.

Fowl 79. Ovary contains a number of typical pullorum ova. Pure culture of *B. pullorum* was obtained.

Fowl 81. Ovary contains large ova apparently normal. There are some small brownish ova that may or may not be infected. Liver contains a few necrotic spots. Cultures from both liver and ovum gave negtive results.

Fowl 82. Large ova apparently normal. Some small brownish ova that may or may not be infected. Liver contains a few whitish spots. Cultures from both liver and ova gave negative results.

On September 24, the following control birds were killed by bleeding, and serum was saved for agglutination tests: Fowls 86, 74, 88, 89, 97, 98, and 99. All were normal, and cultures were negative except for fowl 88, which had reacted to the wattle test. This bird was found to possess a typical pullorum ovary, and yielded a pure culture of *Bacterium pullorum*.

In preparation for another set of trials of the test upon artificially infected fowls, on August 26, 1915, the following birds received intravenous injections of 1 c. c. of bouillon culture of nine strains of *B. pullorum* mixed: Fowls 28, 67, 85, 182, 294, 204, and 215. On September 7 the following birds were injected intraabdominally with 5 c. c. of a similar mixture of strains: Fowls 16, 18, 32, 34, 36, 37, 38, 39, 45, 46, 47, 48, 49, 64, 65, 69, 76, 178, 190, and 197. Fowls 28, 85, and 215 died shortly after the injection.

The birds were tested with killed bacterial culture. The results of the two tests, with autopsy findings and results of cultures inoculated from the ovaries, are given in Table VII.

TABLE VII.—*Two tests with nonconcentrated killed culture.*

Fowl No.—	Dec. 7–8.		Feb. 9–10.		Autopsy Mar. 16.	Cultures
16	+	+	+	−	Questionable	−
18	+	−	−	−	Positive	+
32	+	+	+	+	do	+
34	−	−	Trace.	−	do	+
36	+	+	Trace.	−	Questionable	−
37	−	−	+	−	do	−
38	+	+	+	Trace.	Positive	−
39	+	+	+	−	Normal	−
45	+	+	+	−	do	−
46	+	+	Trace.	−	do	−
47	+	+	+	+	Positive	−
48	+	+	−	−	Normal	−
49	+	+	Trace.	−	Questionable	−
64	+	+	+	−	Positive	+
65	+	−	−	−	Normal	−
67	+	+	Trace.	−	Positive	−
69	+	−	+	−	Questionable	+
176	+	+	+	−	Positive	+
178	+	−	+	Trace.	do	+
190	+	+	+	Trace.	do	−
197	+	−	−	−	do	+
182	+	+	+	Trace.	do	−
204	+	+	+	Trace.	Questionable	−
294	+	−	Trace.	−	Normal	−
41 [1]	−	−	−	−	Not killed	
42 [1]	−	−	−	−	do	
77 [1]	−	−	−	−	Normal	
278 [1]	+	−	−	−	Died	−
179 [1]	−	−	−	−	Normal	
80 [1]	−	−	−	−	Not killed	
181 [1]	−	−	−	−	do	
101 [1]	−	−	−	−	do	
102 [1]	−	−	−	−	do	
103 [1]	−	−	−	−	do	

[1] Controls.

SUMMARY OF THE TESTS WITH ARTIFICIALLY INFECTED BIRDS.

In the course of the experiments recorded in the foregoing, 32 birds that had been exposed to infection by injection of live cultures were employed. When tested for the first time 29 of these, or 90 per cent, revealed edematous swellings rated as either slight or positive at 24 hours after injection with the diagnostic agent. When read at a 48-hour interval, 23, or 71 per cent, of the same birds gave reactions rated as either slight or positive. Thus, the 24-hour interval yielded the largest percentage of reactions. Practically all birds, both those inoculated and controls, exhibited a swelling shortly after injection and therefore no diagnostic value has been attributed to swellings observed before the lapse of 24 hours.

Three birds gave negative readings at both 24 and 48 hours. Autopsy of two of these revealed unquestionable lesions of pullorum infection, from which the organisms were obtained, while in the third one the lesions were questionable and no culture was obtained. Thus, the test failed to detect 6 per cent of the birds in which lesions were found.

In all but two cases the same birds were retested after an interval of 7 or 8 weeks. Of the 30 birds retested 22, or 73 per cent, gave a reaction rated as either a trace, slight, or positive at 24 hours on the second test. At 48 hours on the second test only 8, or 26 per cent, displayed reactions rated as a trace, slight, or positive. Further, 8 birds, or 26 per cent, showed no reaction at either 24 or 48 hours. It is evident that a retest after an interval of about 8 weeks is far less reliable than a first test.

Of the 32 birds tested, autopsy revealed unquestionable lesions in 18, or 56 per cent. In 8, or 25 per cent, the lesions were regarded as questionable. In 6 birds, or 16 per cent, no lesions were found, although all were positive to the test at 24 hours.

Twenty-six controls were tested for the first time. These had been gathered from various sources and there was no assurance that they were free from infection. Of these, 5 at 24 hours after injection displayed swellings rated as slight or positive and 4 displayed the same condition at 48 hours. At autopsy 2 were found to be infected, and 1 through accident was not examined. No lesions were found at autopsy of 2; however, 1 of these came from the same flock as one of the unquestionably infected controls, and had been in the same cage as the infected bird.

While agglutination tests were made on serum drawn from inoculated birds, after injection with the diagnostic agent, and the results appear in the various tables, it is realized that agglutination would naturally be expected as a result of the various injections. We have observed that as a result of the artificial infection with cultures of *Bacterium pullorum*, the agglutinating value of the serum of these birds varied within a wide range. Some birds gave an agglutination at a dilution of 1:1,000, while others that had been repeatedly injected with the test fluid gave no agglutination, owing to the strong bacteriolytic properties of their sera, presumably resulting from the various injections. Negative control birds after one injection with the test fluid gave an agglutination titer of 1:50.

The disadvantages of work with artificially infected birds, due to the large amounts of culture injected and to the severe reactions resulting, were thoroughly realized, and work with naturally infected birds was undertaken.

FIELD TRIALS OF THE INTRADERMAL TEST.

Through the courtesy of the Connecticut agricultural experiment station, opportunity was afforded to apply the intradermal test to two flocks tested at the same time by Dr. L. F. Rettger by the agglutination method.

One flock of 231 birds injected on February 28, 1916, contained at the time over 40 birds showing more or less evidence of swelling of the wattles due to frostbite, while 6 others showed very slight swelling attributed to the same cause. When examined 38 hours after injection none was regarded as showing reaction to the intradermal test. One bird gave a reaction to the agglutination test and was killed by the owner before arrangements were made to retest by the intradermal method. However, the owner had made an autopsy and reported that he regarded the bird as infected.

In the second flock in which work was done the Connecticut Agricultural Experiment Station tested 50 birds in the regular routine work of testing. Of these 1 reacted to the agglutination test and failed to react to the intradermal test when examined 46 hours after injection. A number of birds showed slight abnormal conditions, regarded at the time as due to frostbite, but noted in connection with the problem of determining the least amount of swelling to be regarded as a significant intradermal reaction, under the conditions in question.

The bird that gave a positive reaction to the agglutination test was retested by both methods about a month later by Dr. Rettger. At 24 hours after injection the wattle was swollen to about 2.5 times normal thickness, and when observed at 48 hours the swelling was 1.5 times normal. An agglutination test made at the same time also gave positive results. It is probable that the failure of the intradermal test when used the first time was due to some error in technique. Further, it is the belief of the writers that readings should be taken at about 24 hours, and not as late as 36 and 48 hours, as in these trials.

In the same flock the intradermal test alone was applied to about 100 birds, and those showing any enlargement of the wattle at 46 hours were tested by the agglutination method by Dr. Rettger. The results yielded by both methods are given in Table VIII. The size of the swelling following the intradermal injection is indicated as nearly as possible by arranging them in order of decreasing size from the top to the bottom of the list. Here, again, cognizance was taken of every degree of swelling, without implying that the slighter swellings were significant.

TABLE VII.—*Comparison of intradermal and agglutination tests.*

Fowl No.—	Intradermal test.	Agglutination test.	Fowl No.—	Intradermal test.	Agglutination test.
93	Whole wattle swollen, ×3; droops..	–	66	Swelling and drooping of feathered skin at edge of wattle.	–
76	Whole wattle swollen, ×3	+	52	Trace of swelling at lower edge of wattle	–
77	Lower half swollen, ×3	+	99	Swelling possibly due to traumatism, as wattle is very blue	–
73	Swollen, ×2	–	60	Questionable swelling of feathered skin at edge of wattle	?+
72	Swollen, ×2	(?)	95	Trace of swelling on posterior half of wattle	–
96	Swollen, ×2	–			
29	Lower half swollen, ×2	–			
59	Lower half swollen, ×1.5	–			
81	Lower half swollen, ×1.5	–			
100	Lower half swollen, ×1.5	–			
97	Lower half swollen, ×1.5	–			

The results were particularly discordant in the case of fowl 93, which had been placed at the top of the list as showing the best intradermal reaction, while it failed to give a reaction to the agglutination test. In view of the discrepancy, Dr. Rettger obtained the bird in question, together with three others, for retest and autopsy. The results are shown in Table IX:

TABLE IX.—*Comparison of retests and autopsy findings.*

Fowl No.—	Intradermal test. 24 hours.	Intradermal test. 48 hours.	Agglutination test.	Condition of ovaries at autopsy.
93	Slight	–	–	Normal.
72	Swollen, ×2	Swollen ×1.5	–	Do.
29	–	–	–	Normal (small).
60	–	–	–	Normal.

The result of the retest and autopsy of birds 93 and 72 is not wholly satisfactory. The repetition of the reaction in both cases is significant; but, on the other hand, the results of the agglutination test and autopsy leaves the matter inconclusive. As to the remaining discrepancies in Table VIII, the many other cases noted as surely the result of freezing indicate that it is not desirable to apply the intradermal test where there is a possibility of freezing.

TRIALS BY OTHER INDIVIDUALS.

In several instances the test product was sent to interested individuals on request. One report on the results was received in which 1,301 birds were tested and 78 gave a positive reaction. The latter were retested by the agglutination method, and 70 gave a positive reaction.

COMPARISON OF RESULTS OF AGGLUTINATION AND INTRADERMAL TESTS ON NATURALLY INFECTED BIRDS.

Through the assistance of Roy E. Jones, we located and purchased 47 birds that had given positive or questionable agglutination tests, applied by the Connecticut Agricultural Experiment Station. These, together with nine controls, were injected for the intradermal test on June 23, 1916, and readings were taken at 24 and 48 hours.

Of the birds reported positive to the agglutination test applied by the Connecticut station, there was total agreement in 28, or 70 per cent, of the cases in that they also gave positive intradermal test as determined 24 hours after injection and displayed unquestionable lesions when eventually slaughtered. Of those reported positive to the agglutination test, 30, or 75 per cent, revealed lesions at autopsy.

Thirty-five birds gave positive reactions to the intradermal test. Autopsy revealed that of these 29, or 83 per cent, possessed undoubted lesions, in 5 the lesions were questionable, and in 1 no lesions occurred. Of those reported positive to the agglutination test, 3 birds, or 7 per cent, failed to react to the intradermal test, and autopsy revealed no lesions. On the other hand, 2 birds, or 5 per cent, that had given positive agglutination tests, gave negative intradermal tests, and autopsy revealed lesions. Thus, the percentage of absolute failures of each test as judged by the other test and by the autopsy findings were very similar in amount.

Seven birds had given questionable agglutination tests. Of these, 3 were negative to the intradermal test and negative at autopsy. One reported questionable gave a positive intradermal reaction and autopsy revealed lesions. The intradermal test on the other 3 yielded positive, negative, and questionable results, respectively, and autopsy of all 3 furnished inconclusive information.

Of the nine controls, one displayed a marked reaction at 24 hours, consisting of a swelling of the wattle to three times its normal thickness. Autopsy revealed undoubted lesions, and a pure culture of *Bacterium pullorum* was isolated from the ovary. Four others displayed traces consisting of swelling of the lower border of the wattle to about twice the normal thickness. On autopsy, one of these was found to contain undoubted lesions and a pure culture of *B. pullorum* was obtained.

The examination of the wattles at 48 hours revealed swellings varying from a trace to positive in only 22 birds, or 46 per cent, of those tested. This result compared with the 28 birds regarded as positive at 24 hours and verified by subsequent autopsy, again indicates that 48 hours is too long to secure all the positive reactions. Among the controls only 1 displayed any swelling whatsoever, and this case proved on autopsy to be positive.

On June 26 all the 47 birds and 9 controls were reinjected and examined 5 hours later. At this time every bird, including controls, displayed a swelling varying in the different individuals from a trace to five times the normal thickness. The observation merely emphasizes the fact of the occurrence of a nonsignificant swelling following injection with the diagnostic agent.

At 24 hours 39 birds displayed swelling of the wattle varying from a trace to enlargement to five times the normal thickness. Autopsy revealed undoubted lesions in 30 of these, questionable lesions in 7, and no lesions in 2. Total agreement between the results of this reading, the agglutination test, and autopsy findings occurred in 70 per cent of the birds tested. In two cases, or 4 per cent of the birds, the positive readings by the agglutination test were not supported by the negative results of the intradermal test and the autopsy. In 1 case, or 2 per cent, negative results of the intradermal test were contradicted by the positive results of agglutination test and autopsy. Thus, the results yielded by the first and second 24-hour readings of the test on supposedly infected birds vary but little.

The results yielded by the test on the control birds were perfect, as confirmed by the autopsy. The only two birds that displayed traces of swelling proved on autopsy to be infected.

The fact that the results of the agglutination test, intradermal test, and autopsy are in complete agreement in 70 per cent of the cases, coupled with the fact that the absolute diagreements are very small, indicates that the two tests are equally accurate.

The results obtained at the autopsy of the birds emphasize the difficulty of determining a standard for comparison of the accuracy of the two tests under trial. Thirty-one cases, or 64 per cent, were found to possess unquestionable lesions consisting of the angular ova characteristic of the infection. All of the cases had given positive reactions to one or both tests. In nine cases, or 10 per cent, the autopsy was inconclusive in that there were present only very small dark ova or cysts. Of these 9 questionable cases 3 had given questionable agglutination readings but positive intradermal reactions. In two cases the agglutination and intradermal tests disagreed. In four cases both tests had given positive results.

SIGNIFICANCE OF SWELLING AS AN INDICATION OF A REACTION.

In determining the significance in diagnosis of an edematous swelling of a wattle one is confronted with the fact that in all birds such swelling occurs shortly after injection. The problem is to determine the point of time after injection to read the test when this preliminary swelling has disappeared, yet not too late to escape observing a significant edema. The tests on birds in the laboratory and probably also those in the field indicate that 48 hours is too late. While some observations on birds in the field made during freezing weather would indicate that slight swellings should not be considered, yet the entire experience with birds in the laboratory indicates that even a trace may be indicative of a positive reaction. Some few cases would indicate that a 24-hour reading might give false results due to the inclusion of some cases in which the preliminary nonsignificant swelling had not quite subsided. At present, the 24-hour interval has given the best results, but the examination of a series of readings at 30 hours would be desirable.

VARIOUS BIOLOGIC TESTS.

During the course of these experiments several attempts were made to produce a reaction to the diagnostic agent by injection into the comb, but no satisfactory results were obtained. The ophthalmic, palpebral, and subcutaneous tests also failed to produce a reaction. Also limited complement-fixation tests on the blood serum of infected fowls gave uncertain readings.

SUMMARY AND CONCLUSIONS.

A killed culture of *Bacterium pullorum* grown for about a month and held for several weeks before use and without further treatment other than carbolizing, has given the most satisfactory results.

It seems to be a fact that the edematous swelling resulting from the injection of this product into the wattle of a fowl, when observed at a proper time interval, is an indication of the presence of infection of *B. pullorum* in the fowl.

Our experience to date with readings at various time intervals leads to the conclusion that the 24-hour interval has given the most accurate results. However, it seems desirable to test on a large number of birds the accuracy of readings made at a slightly longer interval.

The weight of evidence indicates that any perceptible swelling of the wattle should be regarded as significant. A second intradermal test made at an interval of four days gave results varying but little from the first test. Others made at intervals up to two months gave less accurate results the second time. Thus, there is no advantage in retesting.

Of birds artificially infected with the disease and tested in the laboratory, in round numbers 90 per cent gave positive reactions; and in 6 per cent the test failed to indicate a reaction when lesions were present. In 3 per cent no reaction occurred and no lesions were present.

In a field test on 231 birds made simultaneously with the agglutination test, the intradermal test at 38 hours failed to detect one case reported positive to the other test. In a second flock of 50 birds in which the two tests were compared, the intradermal test when read at 46 hours failed to indicate one case that was detected by the agglutination test. Another group of about 100 birds tested under unfavorable conditions gave less satisfactory results.

Forty-seven birds that had been tested by the agglutination method by the Connecticut Agricultural Experiment Station in the field were purchased for experiments with the intradermal test. Of these, 40 had given positive reactions to the agglutination test and 7 doubtful reactions. There was complete agreement between the agglutination test, the intradermal test, and autopsy findings in 70 per cent of the cases. The agglutination test reported positive in 3 cases, or 7 per cent, was not confirmed by the intradermal test nor by the autopsy findings. The result of the intradermal test was negative in 2 cases, or 5 per cent, when it was not confirmed by the positive agglutination test and autopsy findings. Thus the percentage of absolute failures of each test was small and very similar for both tests.

Autopsy does not furnish an absolute standard for comparing the accuracy of tests. Seventy-two per cent only of naturally infected birds that had reacted to one or both tests were found on autopsy to be unmistakably infected.

The intradermal test detected the presence of infection in 4 of the 34 control birds injected in connection with the tests in the laboratory on artificially and naturally infected birds.

In a field trial not made by the writers, 1,301 birds were tested intradermally and 78 reacted. Of these 70 reacted to the agglutination tests made subsequently.

The intradermal test has already shown sufficient promise to warrant further extensive trials in the field in comparison with the agglutination test.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 518

OFFICE OF THE SECRETARY
Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief

Washington, D. C. ▼ March 17, 1917

THE COST OF PRODUCING APPLES IN HOOD RIVER VALLEY

A DETAILED STUDY, MADE IN 1915, OF THE CURRENT COST FACTORS INVOLVED IN THE MAINTENANCE OF ORCHARDS AND THE HANDLING OF THE CROP ON 54 FARMS

By

S. M. THOMSON, Scientific Assistant, and
G. H. MILLER, Assistant Agriculturist

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THE COST OF PRODUCING APPLES IN HOOD RIVER VALLEY.[1]

A Detailed Study, Made in 1915, of the Current-Cost Factors Involved in the Maintenance of Orchards and the Handling of the Crop on 54 Farms.

By S. M. THOMSON, *Scientific Assistant*, and G. H. MILLER, *Assistant Agriculturist*.

CONTENTS.

During the summer of 1915 an investigation was conducted with reference to the factors entering into the annual cost of producing apples in the Hood River Valley of Oregon (see fig. 1) up to the point of delivery at the shipping station. On account of orchards being of varying ages, and operated in some instances by absentee owners, it was difficult in many cases to secure accurate data.

However, 54 complete and detailed records of orchards were secured. All these were obtained from growers who supervised their own orchards and who were able and willing to give complete information.

The purpose of this investigation was not only to arrive at the annual cost of production, but to determine the economic status of

[1] This is the third of a series of bulletins on the cost of apple production. Department Bulletin No. 446, "The Cost of Producing Apples in Wenatchee Valley, Washington," and Department Bulletin No. 500, "The Cost of Producing Apples in Western Colorado," have already been published.

NOTE.—Acknowledgment is due to the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry for material assistance in the preparation of this bulletin; also to Mr. J. Clifford Folger, who aided in securing the necessary data.

the apple industry in the valley and the general farm-management conditions prevailing in the region.

The method of investigation was to question the grower on all items of labor and materials used, system of management, yield, and every other factor affecting the annual cost of operating an orchard. Throughout this entire bulletin the acre is the unit used, thus giving each record or orchard the same weight in the final averages.

Four kinds of costs are considered in arriving at the total annual cost of production: (1) Maintenance, (2) handling, (3) material, and (4) fixed charges.

Labor costs.		Costs other than labor.	
Maintenance.	Handling.	Material.	Fixed.
Manuring. Pruning. Disposal of brush. Plowing. Cultivating. Sowing mulch crop. Handling mulch crop. Propping. Thinning. Spraying. Miscellaneous.	Picking. Hauling shooks. Hauling to packing house. Packing. Sorting. Waiting. Foreman. Nailing. Haul to station.	Manure. Lime-sulphur. Lead. Bordeaux, $CuSO_4$. Box. Nails. Paper.	Taxes. Insurance. Equipment charge. Apple-house depreciation. Interest. Water rent.

FACTS BROUGHT OUT.

Total costs.—It is found that the total cost of apple production for 54 bearing orchards, representing the commercial and well-cared-for orchards of Hood River Valley, is $1.02 per box. Costs per acre are $222.83 for orchards under clean cultivation and $232.32 under mulch crops. (See Table I.)

Analysis of costs.—The cost per box, exclusive of interest on orchard-land investment, is $0.68 for clean-cultivated orchards and $0.645 for orchards in mulch crops or irrigated, or $0.664 for all orchards.

Net labor costs for all records average $0.383 per box, or 37.5 per cent of total cost (17.6 per cent is for maintenance and 19.9 per cent for handling).

Costs other than labor, including all material and fixed costs, constitute 62.5 per cent of the total cost (18.9 per cent for material and 43.6 for fixed charges). The fixed cost is nearly 70 per cent of all costs other than labor. Interest on orchard-land investment alone is $79.26 per acre, or $0.357 per box—approximately 35 per cent of the total cost of production.

The cost per box (labor, material, and fixed charges) up to the time when the apples are ready to harvest from the trees is $0.676, while the cost of labor and material for harvesting is $0.345. The total labor and material cost for harvesting is 33.77 per cent of the total of all costs.

Credits.—Cull fruit pays a net annual cash credit of $4.06 per acre (gross $5.13, less $1.97 per acre for extra labor on culls).

Twenty-four mulch-crop orchards show an average annual credit of $6.18 per acre for hay (gross $9.59 per acre, cost of harvesting $3.41).

Size and type of farms.—The 54 farms studied average 39.45 acres in size, with 69 per cent of the farm area tillable. Apples and strawberries are the staple fruits. Considerable quantities of alfalfa and of timothy are grown and a small acreage of grain.

The orchards.—The orchards studied average 12.4 acres in size, 12 years of age, and 72 trees to the acre. Apple orchards constitute 32 per cent of the total farm acreage. Yellow Newtown and Esopus are grown, practically to the exclusion of other varieties.

Investments.—Total investment per farm is $23,487.36; per acre of apple orchard, $990.74.

Orchard management.—Thirty of the 54 growers practice clean cultivation, while 24 use mulch crops, usually in the form of alfalfa or clover. In general the clean-cultivated orchards are not as yet irrigated, while all the mulch-crop or shade-crop orchards are under irrigation.

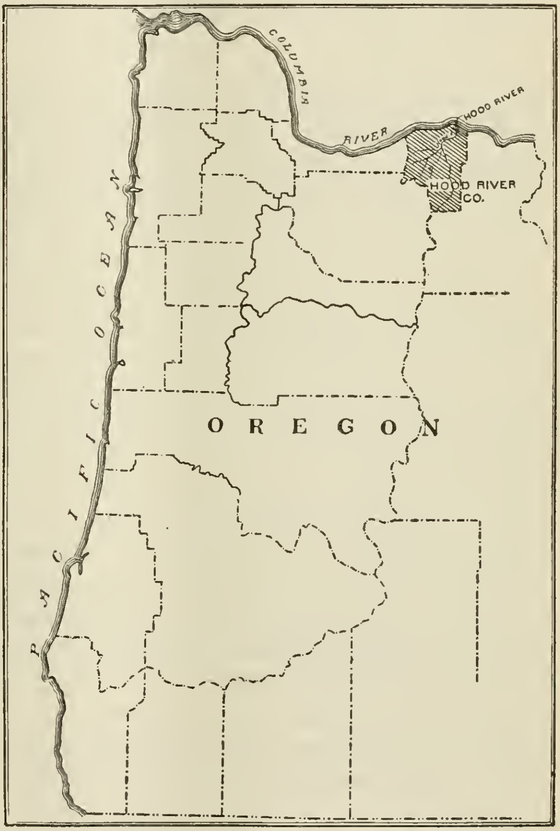


FIG. 1.—Map of western Oregon showing the location of Hood River Valley where the investigation was made. The shaded area is Hood River County.

Yield.—The average yield, all records, is 222 boxes per acre; for clean-cultivated orchards, 218; for mulch-crop orchards, 228. This refers to packed boxes of marketable fruit only.

TABLE I.—*Summary of costs after crediting orchard with hay and culls.*

Item.	Clean cultural (30 records).			Mulch crop or shade crop (24 records).			All records (54).			
	Cost per acre.	Cost per box.	Per cent of total.	Cost per acre.	Cost per box.	Per cent of total.	Cost per acre.	Cost per tree.	Cost per box.	Per cent of total.
Maintenance	$43.63	$0.2001	19.58	$35.41	$0.1554	15.25	$39.97	$0.555	$0.1801	17.63
Handling	44.15	.2025	19.81	46.27	.2029	19.91	45.08	.626	.2031	19.88
Material	41.12	.1886	18.46	45.06	.1976	19.40	42.80	.594	.1927	18.86
Fixed	93.93	.4309	42.15	105.58	.4632	45.44	99.11	1.376	.4458	43.63
Total	222.83	1.0221	100.00	232.32	1.0191	100.00	226.96	3.151	1.0217	100.00

CONCLUSIONS.

In general it may be said that the results of this study bear out the reputation of the Hood River Valley as a very progressive fruit district, the success and fame of which are due to the efforts of its settlers and organizations, together with the realization that a good trade name could be obtained and held only by putting on the market a first-class and reliable product. The conclusion is inevitable, however, that the popularity of the valley is also due to its almost unparalleled scenic beauty, and that the price of land has been determined, not only by considerations of agricultural value, but also by the fact that the valley is a highly desirable place of residence.

The following specific conclusions apply directly to the business of apple production on the 54 farms studied:

(1) The average grower must get over $1 per box for apples, f. o. b., to realize any profit above interest on his investment, and must get $0.67 per box before he begins to realize any interest.

(2) Even though in some cases fruit does not pay full interest on investment in high-priced land, it does not necessarily follow that fruit should not be grown, since it probably pays a higher interest than any other crop would.

(3) Though the cost per acre increases as the yield increases, the cost per box decreases. Hence, efforts to cut the cost of production should be devoted primarily to increasing the acre yield of marketable fruit.

(4) Investment and fixed costs are as high per acre where the yield is small as where it is large. Thus, a yield of 200 boxes per acre costs 100 per cent more per box for fixed costs than a yield of 400 boxes.

(5) Farms in the valley are, in general, over-specialized. In many cases it is now almost impossible to diversify enough to insure the production of a fair proportion of the farm products consumed on the farm.

(6) Though the average yield of the valley is lower than that of some other sections, the region studied, however, produces apples of the very highest quality.

(7) The valley is particularly well adapted to the production of Yellow Newtown and Esopus, both of which grow to perfection here.

These conclusions, of course, apply to the 54 farms studied in the valley. Individual growers often obtain much better results than those indicated by the averages here presented; indeed, in some years exceptional yields run as high as 1,000 boxes per acre. It is believed, however, that the averages derived from the records of the 54 farms studied are a fair measure of the normal business of the apple industry of the valley.

Considering the residential advantages of the locality, the high grade of the fruit shipped, and the valley's already long established reputation for high quality of product and reliability of pack, it seems reasonable to conclude that Hood River Valley will continue to occupy an important place in the apple-growing industry.

THE HOOD RIVER VALLEY.

For several reasons Hood River Valley, although studied in connection with apple-growing regions in other parts of the Northwest, should be discussed as a unit. It is more or less isolated and is of limited extent, presenting conditions not comparable with those of such apple-producing regions as the Wenatchee and Yakima Valleys in Washington State or the apple-producing localities of western Colorado. It is a region with a rainfall equaling that of New York. It thus has a climate which is often very favorable to fungus troubles. It has not been irrigated until recently, and much of it is still unirrigated. The trees have a different habit of growth, with a lower average annual yield, than the trees of most other apple sections of the Northwest. The fact that Yellow Newtown and Esopus are the leading commercial varieties of the valley accounts very largely for the lower average yield as compared with some other sections. These varieties are characterized by bearing smaller annual crops. It is a highly specialized fruit region which has developed its own name, its own methods, and determined its own success. In many respects it is entirely different from other important apple-growing districts.

LOCATION AND EXTENT.

The Hood River Valley is a limited area, 80 miles east of Portland, Oreg., on the south side of the Columbia River.

The Hood River rises at the foot of Mount Hood and flows for about 30 miles north into the Columbia River, the town of Hood

River being located at its mouth. (See fig. 2.) The valley is narrow, varying from 2 to 8 miles in width, and the cultivated area extends from the town of Hood River to Parkdale in the upper valley, a distance of about 24 miles. It is divided into what are known locally as the lower, middle, and upper valleys. The lower valley contains the most bearing fruit and the greatest percentage of tillable land. The middle valley is considerably less intensive in

FIG. 2.—A topographical sketch of Hood River Valley, looking south from the north bank of the Columbia River.

its agriculture, being to some extent devoted to general farming, while the upper valley is as yet little cleared, the small settlements being scattered and separated by areas heavily wooded with pine.

The Hood River divides the valley into what is known as the east side and the west side. The east side is the more developed and intensive. It is of a less rocky nature and seems better adapted to fruit. The best bearing apple orchards are now found on the east side, which is much narrower than the west side, but the cultivated area of which extends much farther up the valley. More general farming is found on the west side, and less detailed care is given the orchards there. The Oak Grove district, a large district on the west side, has many beautiful homes of people who have ranches for pleasure as well as for profit.

Pine groves and trees are numerous, and add greatly to the natural charm of the region. Mount Hood to the south and Mount Adams to the north, both beautiful mountains and continually capped with snow, add a crowning touch of grandeur to the landscape that has made this valley famous for its natural beauty. (See plates I and II.)

Hood River is a fast-flowing stream; it is really a mountain brook. (See Pl. III.) There are no broad, level, flat lands that one thinks of as characterizing a river valley. The orchards are located on the benches and rolling land between the stream bed and the mountains on each side. The topography is extremely varied, and is a combination of buttes, slopes, rolling hills, and fairly level fields, often cut up with little creeks. The areas of level ground are very limited in extent.

COMMERCIAL IMPORTANCE OF HOOD RIVER.

The popularity and commercial importance of Hood River are based not so much on the quantity of fruit shipped, as on its quality, and the dependence the trade has learned to place in Hood River apples. The apples of Hood River are largely limited to two very important commercial varieties which grow to perfection here. These varieties are Yellow Newtown and Esopus.

According to the census figures, there are 60,345 acres of tillable and 62,598 acres of nontillable land in Hood River County. Of the tillable area 13,446 acres, or 22 per cent, are in apple orchards, and of this amount there are 2,665 acres, or about 20 per cent, in trees 10 years of age or over. Seven hundred and fifty cars of apples were shipped out of the Hood River Valley district in 1911, 1,100 cars in 1912, 1,050 cars in 1913, and 1,200 in 1914, or an average of about 1,000 cars per year. The usual number of packed boxes per car is 630.

AGRICULTURAL DEVELOPMENT.

The first settlers in the valley occupied mainly the narrow strip of alluvial soil along the Columbia River and the more level parts of the valley above. The isolation of the valley retarded its development, and the lack of market, together with the fact that all produce had to be shipped by boat on the Columbia River, limited the agricultural activities almost exclusively to stock raising. The early farming was confined principally to those areas where there was little or no timber. The valley was for the most part heavily timbered, particularly on the east side. For many years the only work done in clearing was on the small tracts around the settlers' cabins, which supplied all the land necessary for agricultural purposes until markets became available.

The first orchard in the valley was planted about 1875, on the west side, but none of commercial importance was planted before 1890. From this time on the plantings increased, the maximum amount of planting being done between 1902 and 1909. During the last few years plantings have largely ceased.

The west side having a sandy soil, it was thought for many years to be the only part of the valley suitable for profitable fruit growing. At the present time it is the principal strawberry-producing section. The more sandy soils of the valley seem particularly adapted to strawberries, and the strawberry industry held an important place in the agriculture of the valley long before the apple became dominant. On account of the higher altitude the upper-valley strawberries ripen much later than those of the lower valley, thus giving the district a long marketing season.

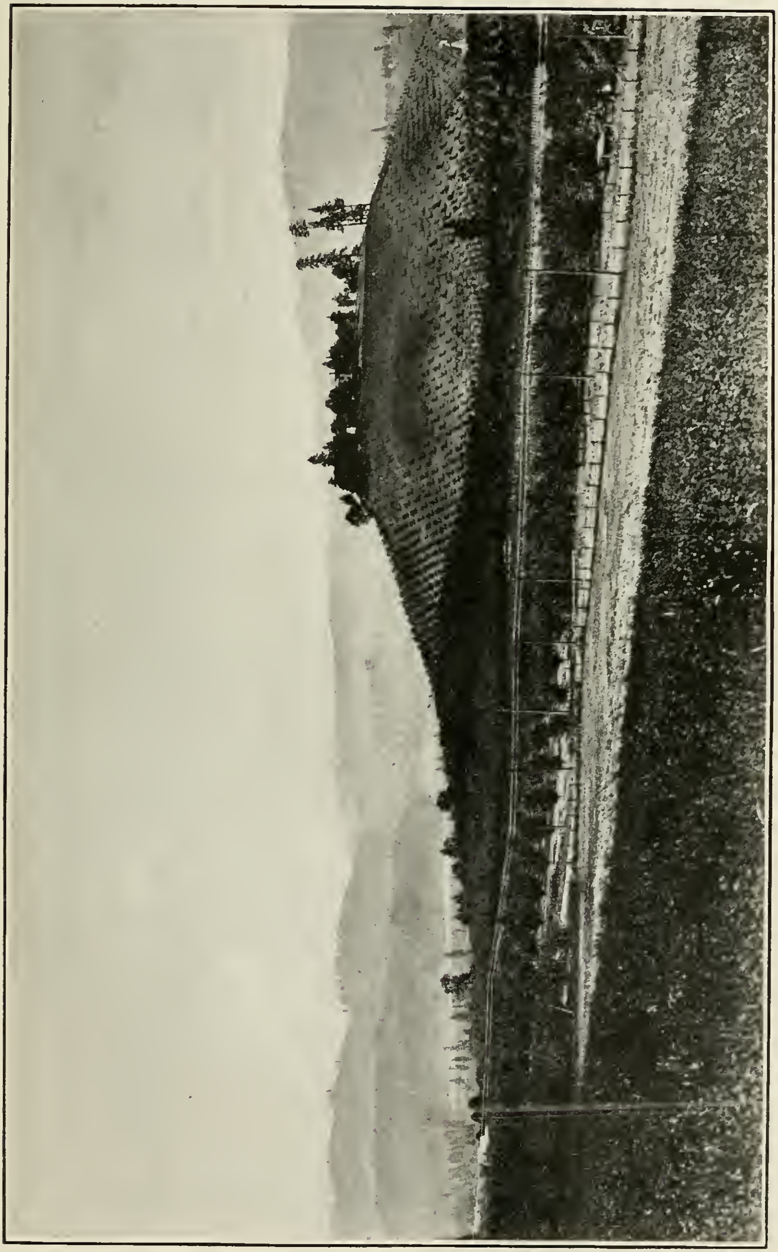
Apples have been planted almost to the exclusion of other orchard fruits. The land on the east side was developed later than that on the west side, but when it was found that the land on the east side was well adapted to apples it was rapidly bought up in small tracts, cleared, and set out to orchard. The east side has now considerably more orchard area than the west side, the farming being more intensive, and devoted more largely to commercial fruit production. (See Pl. IV.) The more recent settlers confined their attention almost wholly to fruit farming. As the demand for land increased the price rose very materially. To avoid these high prices the newer settlers often located on the slopes, in many cases above the irrigation canal, and in the upper Hood River Valley, where the land as yet is little cleared.

Recent development of transportation facilities has contributed to the valley's rapid development.

SOIL.

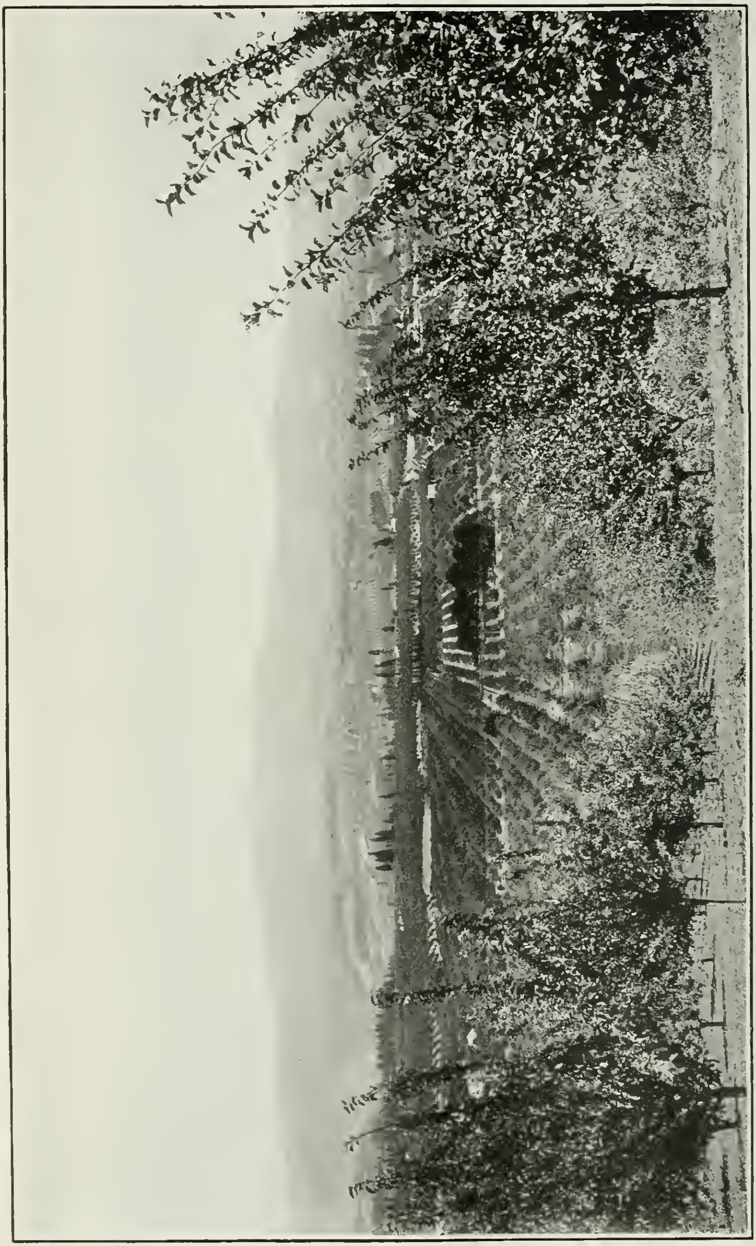
The Hood River Valley is located within the area of an important rock formation known as the Columbia lava. Thus, the soil of the valley is in general of volcanic origin, modified by glacial action.

The commercial orchards of the lower valley are for the most part located on the Hood silt loam type of soil. The Hood silt loam is generally of a light gray color. The silt content is low and it often approaches a sandy loam in texture. This soil covers the greater



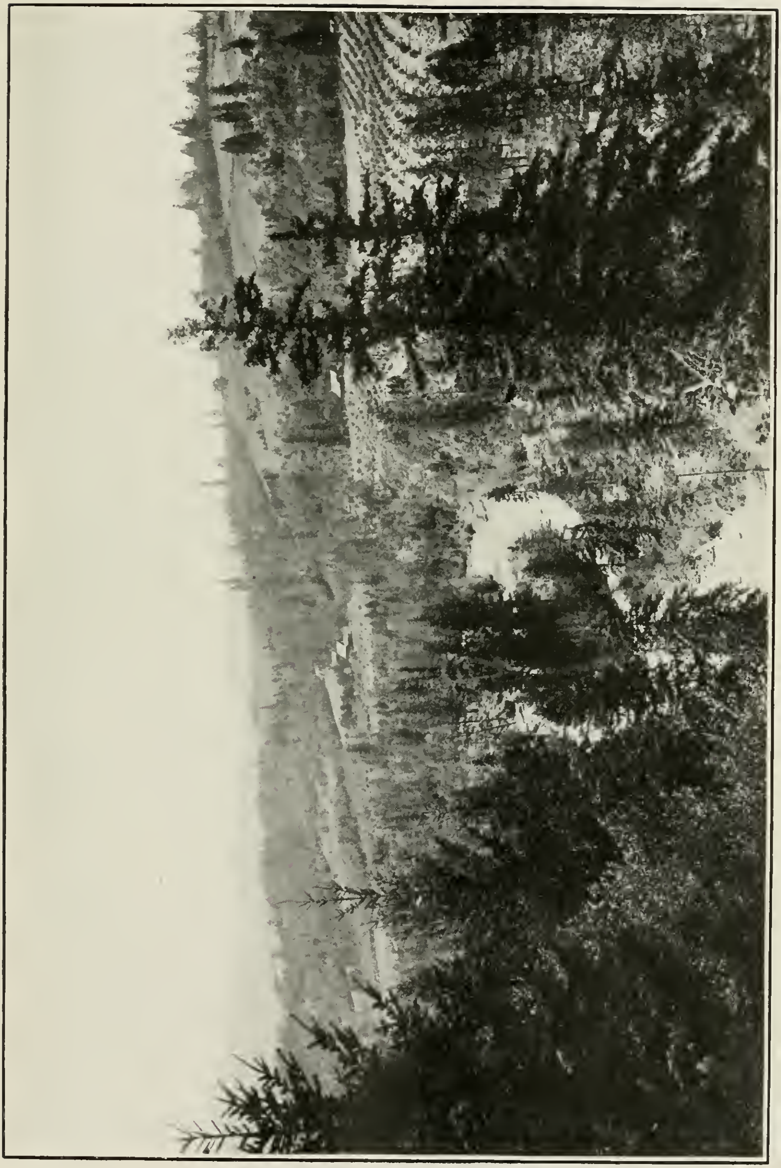
VIEW OF THE VAN HORN BUTTE, FAMOUS AS A BEAUTIFUL RESIDENTIAL SPOT, WITH MOUNT HOOD 25 MILES AWAY IN THE DISTANCE.

The natural beauty of Hood River has added greatly to its popularity and brought many desirable settlers. Land in this immediate region is valued at $1,000 or more per acre.

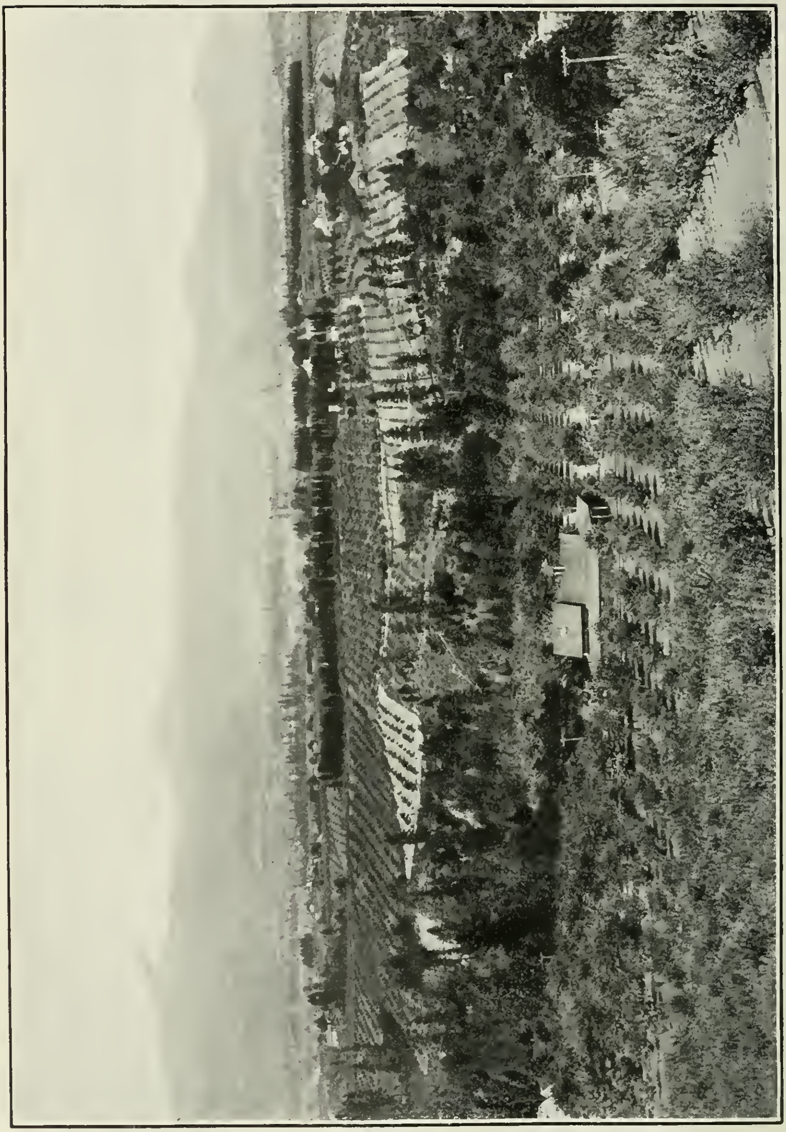


LOOKING ACROSS HOOD RIVER FROM THE PETER'S RANCH, ON THE EAST SIDE OF THE LOWER VALLEY.

The most intensive apple section of the region. The orchard in the foreground is an 80-acre block just coming into bearing, one of the best managed in the valley.



VIEW UP THE HOOD RIVER VALLEY FROM A POINT ON THE EAST SIDE 6 MILES ABOVE THE TOWN OF HOOD RIVER, SHOWING THE NARROW CREEK BED AND THE UNEVEN TOPOGRAPHY.



VIEW ACROSS THE LOWER VALLEY FROM THE MAIN HIGHWAY ON THE EAST SIDE, SHOWING A PACKING HOUSE AND CLEAN CULTIVATED ORCHARD IN THE FOREGROUND.

part of the lower valley between Hood River and the range of mountains along the eastern boundary of the area as far up as Odell. On this area is located the largest and most intensive apple section of the valley. The drainage is generally good.

The soil of the Underwood loam covers the largest areas of the valley, in fact, more than all other types combined. It occurs on the slopes of the mountains in and about the valley. The soils of the middle valley are almost entirely of this type. It is a residual soil, derived from the weathering of the underlying basalt. Its value for agricultural purposes varies according to the topography. With the exception of the steeper slopes the parts which are cleared are used for the production of apples and strawberries.

Many other types of soil are found in the valley. The Parkdale loam covers most of the upper valley. It is probably derived from weathered ice-laid material.

On the west side of Hood River Valley the soils are of the Wind River types, varying from a strong loam to a fine sandy loam. Because of their coarse nature, these soils are rather excessively drained. They need irrigation and are in general more difficult to cultivate than the prevailing types found on the east side of the river. Of all these types the Hood silt loam apparently is the best adapted to apple culture.[1]

CLIMATE.

Hood River is located to the east of the main range of the Cascade Mountains, but in a region of moderately abundant rainfall. It is characterized by moderate winters, with frequent heavy snowfalls, long, rather cool summers, and comparative freedom from damaging frosts. The rainfall, which is approximately 35 inches per year, is equal to that of the apple-growing sections of New York or Missouri, but owing to the fact that there is a rainy and a dry season, it is often desirable to resort to irrigation, which is now becoming a general practice. Destructive storms seldom occur, and damage from hail or storms is infrequent.

Because of the irregular topography there is a marked difference in temperature and precipitation between the different sections of the valley. The number of clear days is considerably greater in the lower than in the upper valley. The length of season may vary a month between the town of Hood River and the town of Parkdale, located in the upper valley about 24 miles to the south. Climato-

[1] U. S. Dept. of Agr., Bureau of Soils, Field Operations 1912, Soil Survey of the Hood River-White Salmon River Area, Oregon-Washington, by A. T. Strahorn and E. B. Watson.

logical records give the average date of the last killing spring frost for the past 15 years in Hood River as April 22. For the same period the average date of the first killing frost in the fall was near October 14. This gives an average of 175 growing days. The mean annual temperature is 50.1° F. This, it should be remembered, is for the lower valley, near the town of Hood River.

Mist-like rains occur frequently during the early summer months. As a result fungus troubles, particularly apple scab, are serious and necessitate a relatively large amount of spraying.

The prevailing winds are from the west. In general, they follow the Columbia River gorge from the coast, thus tending to maintain fairly cool temperatures during the summer season and preventing extreme cold during the winter.

Truck and forage crops naturally adapted to a fairly cool temperate climate succeed well here, provided suitable soil is chosen.

TRANSPORTATION.

The town of Hood River is located on the main line of the Oregon-Washington Railroad & Navigation Co., which gives it easy access to Portland, about 80 miles distant, and also furnishes an outlet to eastern points. There is a local railroad line, known as the Mount Hood Railroad, which traverses the Hood River Valley, connecting the town of Hood River with Parkdale in the upper valley. There are several important fruit-loading stations on this line, including Van Horn and Odell. Transportation by boat on the Columbia River is also available. This was formerly the only means of transportation.

RURAL SOCIAL CONDITIONS.

There are few rural communities where better social conditions exist than in Hood River Valley. The people are for the most part well educated. The excellent schools and churches, the means of recreation, and the systems of telephones and of rural mail delivery which prevail throughout the valley provide advantages as yet unavailable in the average rural community. The homes of Hood River are more elaborate and expensive than the average farmhouse, much of the money invested in them having been made through outside sources. (See fig. 3.) The ranch houses are near together. Indeed, in the lower valley, especially on the west side, they are almost a part of the town itself as regards conveniences. As yet the people in the upper valley are somewhat isolated.

LABOR CONDITIONS.

There is little complaint with regard to labor conditions in this section. The rates paid are not quite as high as in some other Northwest sections. Both whites and Japanese are employed. White help, employed by the month, receives wages varying from \$25 to \$40 per month with board, or \$40 to \$60 per month without board. Much of the orchard work is done with day labor at 20 to 25 cents per hour. Japanese labor is cheaper, costing $17\frac{1}{2}$ cents per hour, and is used largely for strawberries. Growers say the Japanese are good laborers if a white foreman superintends. Except as house servants, Japanese are rarely employed by the month.

On the 54 orchards taken into account in this investigation the average rate paid for all kinds of labor for the past few years was

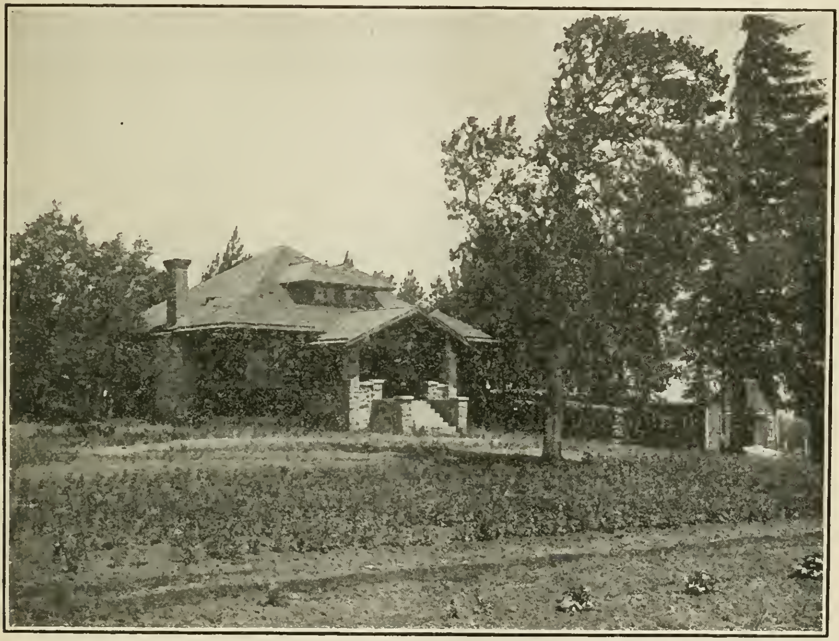


Fig. 3.—One of the many bungalow homes found in the rural districts of the valley.

$22\frac{1}{2}$ cents per hour, or at the rate of \$2.25 per day. Month labor usually is fully as expensive per hour in this region as day labor, for it often occurs that little productive labor is done on certain days where a man is employed by the month. In order to make the records comparable the average rate of $22\frac{1}{2}$ cents per hour is used on all the farms.

An operator's time is charged at the same rate as the men he employs. If he were paid for his managerial ability each operator would receive a different wage; for all practical purposes it is best to figure all man-hours at the same rate. Horse labor is figured at the rate of 15 cents per hour.

FARM ORGANIZATION.

The farms or ranches in Hood River Valley are primarily specialized fruit farms. Other crops are grown mainly or exclusively for home use. These include hay for the horses and garden truck for the use of the farm family. Strawberries work in well with apples and are grown extensively as a cash crop, particularly on the west side of the valley. On account of the small size of the farms and the consequent necessity for intensive operation, together with the high value of the land for fruit culture, it is hardly practicable for growers to follow a diversified system of farming beyond the point of raising feed for the stock kept, and potatoes, garden vegetables, etc., for home use.

Furthermore, the limited area of the valley makes it practically impossible to expand, particularly in the lower valley. Farms have been bought, settled, developed, and organized with fruit as the main, and often the only, source of income. This is particularly true on the east side of the lower valley, where this investigation was made. Because of the natural limitations and the topographical features of the valley, the ranchers do not have easy access to any extended area for general farming purposes. Hence the agriculture of the valley is specialized, and will no doubt remain so, with the farm probably furnishing the greater share of the products required for use on the farm. These conditions make the growers almost wholly dependent on their income from fruit.

TYPE OF FARMS INCLUDED IN SURVEY.

The 54 farms included in this survey are all located on the east side of Hood River and all on the Hood River silt loam soil, with the exception of a very few on the Underwood loam of the middle valley. They range in size from 10 to 150 acres and average 39.4 acres, 69 per cent of which acreage is tillable.

The average size of bearing apple orchard on these farms is 12.4 acres, with an average young apple orchard of 6.24 acres. These farms are typical of the commercial apple district of Hood River Valley and represent the conditions of full-bearing orchards as they exist in the lower valley to-day. Nearly all are intensive and apples are the chief source of income.

TYPE OF GROWER.

Many of these farms are operated by men who came from other walks of life. Several of the growers are college graduates. There are also among them many professional men and tradesmen who chose fruit growing as an occupation after retiring from their professions or trades. The larger farms are usually owned by the pioneers of the valley. These are usually men with considerable agricultural experience. In some cases, however, the man from the city who applies thorough business methods is more successful than his more experienced neighbor.

INVESTMENT.

In Hood River Valley on the 54 farms studied the average investment per farm as estimated by owners is $22,503.70, the average size of farm being practically 40 acres. The average investment per acre

FIG. 4.—A typical ranch 2 miles west of Odell, showing an orchard in bearing and a young orchard planted on land recently cleared of pine. This land was valued at about $250 per acre before it was cleared.

in apple orchards is $990.70. As shown in Table II, the investment is somewhat higher for mulch-crop than for clean-culture orchards. This is due to the fact that those under the mulch-crop system are all irrigated and generally better located than those still under the clean-culture system.

An investment of nearly $1,000 per acre is easily accounted for when all the existing factors which have influenced the price of land are considered. The original raw land suitable for orchard purposes, when fairly well located, sells for $200 to $250 per acre. (See fig. 4.) The cost of clearing this land, which is heavily wooded, usually with pine, is from $90 to $150 per acre.

TABLE II.—*Statistical summary of the 54 apple orchards studied in Hood River Valley.*

Item.	Clean cultural.	Mulch crop.	All records.
Number of records	30	24	54
Acreage per farm:			
Total	44.22	33.50	39.45
In bearing apple orchard	12.25	12.70	12.45
Per cent in bearing apple orchard [1]	39.45	55.03	46.38
Investment per farm:			
Total	$24,704.09	$21,966.44	$23,487.36
Land and improvement	23,673.33	21,041.67	22,503.70
Working capital	1,148.76	1,053.65	1,106.49
Equipment	528.03	446.67	491.87
Horses	349.77	312.50	333.20
Other stock	120.96	154.48	136.04
Investment per acre of bearing apple orchard:			
Total	931.67	1,064.58	990.74
Per cent of total farm investment apple orchard represents	48.93	60.40	54.03
Land and improvement:			
Per cent of total investment in land and improvement apple orchard represents	51.26	63.31	56.61
Equipment	21.51	24.12	22.67
Number of horses per farm	2.33	2.25	2.30

[1] Average of percentage of bearing apple orchard found on each farm.

The price of the raw land throughout the valley was greatly enhanced in the early days by the high prices obtained for fruit. These prices brought many settlers to the valley. The price of land increased with the demand for it, and finally rose to a figure which practically prohibited the man of small means from purchasing land suitable for growing fruit. Men with considerable capital settled in Hood River Valley, attracted largely by the natural beauty of the valley and its advantages as a location for a home. The fact that fruit growing was a thriving business, looked upon as one of the most pleasurable and interesting agricultural pursuits, was of course the principal attraction, but the impressive beauty of the valley was a close second. These unusual attractions determined the price which prospective purchasers could be induced to pay for land.

The price and the actual agricultural value of land are often very different, and they do not bear as close a relation to each other here as is desirable from the standpoint of profit in farming. Hood River Valley, however, is not unique in this respect.

The investment in equipment is high per acre on account of the small size of the average farm in this region. The largest single item of equipment investment is represented by the spraying outfit; 80 per cent of the growers whose records were considered have their own spray rigs. As might be expected, the investment in stock other than horses is small, but is larger on those farms growing mulch crops. They keep more stock because they have the feed for it.

In arriving at interest and depreciation charges no account is taken of investment in dwellings or other buildings not used exclusively for apples. It was not thought fair to charge the orchard with the upkeep or interest on buildings, which often represent an investment far above that of the average farm buildings.

THE ORCHARDS.

SIZE.

The bearing orchards included in this survey vary in size from 3½ acres to 39 acres. In most cases orchards are 10 to 15 acres in size, and the average of all is 12.4 acres. Large farms, as a rule, do not have exceptionaly large orchards. The average farm of 50 acres has as large an orchard as the average farm of 100 acres.

AGE.

The average age of all the orchards considered is 12 years, the youngest being 9 and the oldest 18 years. All these orchards are considered by their owners to be in full bearing. One noticeable characteristic about orchard plantings in this section is the lack of uniformity as regards age. Many planted their orchards over a series of years, so that the number of bearing blocks of uniform age is limited.

TABLE III.—*Size of farms and of orchards studied.*

Item.	Clean cultural.	Mulch crop.	All records.
Average acreage per farm:			
Total	44.22	33.50	39.45
In bearing orchard	12.25	12.70	12.45
In young orchard	7.48	4.69	6.24
Percentage of area tillable	75.75	60.86	69.10
Bearing orchards:			
Average age	12.00	12.00	12.00
Trees per acre	72.00	72.00	72.00

VARIETIES.

The varieties of Hood River Valley apples are principally two—Yellow Newtown and Esopus. The commercial name of the valley has been built up on these apples. Hood River Valley is thus more limited in its number of commercial varieties than any other Northwest section. There are, however, about 75 varieties found in the bearing orchards of the valley. Others of commercial importance are Ortly, Monmouth, Ben Davis, Arkansas Black, Arkansas, Jonathan, Rome Beauty, and Gravenstein. Some of these are often planted as pollenizers. Yellow Newtown and Esopus do not come into full bearing as early as Jonathan, Winesap, Rome Beauty, and most other commercial varieties of the Northwest.

TREES PER ACRE AND METHOD OF SETTING.

The number of trees per acre in these orchards runs very uniform. In the 54 orchards there is an average of 72 trees per acre, and practically all lie between the limits of 60 and 80. There are many methods of setting trees, but the usual way is to set on the diagonal, 24 by 24, 26 by 26, or 28 by 28 feet. The trees are not often crowded.

CONDITION OF THE ORCHARDS.

The condition of the 54 orchards studied was in general very good. The foliage of some of them, however, was discolored and the trees apparently lacked vigor. Such orchards were usually those under a system of intensive clean cultivation and not irrigated. The orchards considered were well cared for and of a fairly uniform type representative of the commercial bearing orchards of the valley.

YIELDS.

The average yields from these orchards are considerably lower than those of many of the irrigated sections. The average yield for the 54 orchards is 222 packed boxes per acre, or 3.08 boxes per tree. This average covers, in general, a 5-year bearing period. For the 30 clean-culture orchards the yield is 218 packed boxes, and for the orchards with a mulch crop, all of which are irrigated, there is a yield of 228 packed boxes per acre.

TABLE IV.—*Hood River yields.*

Type of orchard.	Number of orchards.	Size of orchard.	Age of orchard.	Trees per acre.	Yields per acre.	Yield per tree.
		Acres.			*Boxes.*	*Boxes.*
Clean cultivated	30	12.25	12	72	218	3.03
Mulch crop	24	12.70	12	72	228	3.17
All orchards	54	12.45	12	72	222	3.08

The size of orchard apparently has a marked influence on the acre yield. As will be seen from Table V, the smaller the orchard the larger the yield per acre. As the number of trees per acre is practically the same, regardless of size of orchard, the difference in yield may be credited to the more intensive management of the smaller orchards and the greater care which individual trees receive.

TABLE V.—*Yield, according to size of orchard, on farms studied.*

Type of orchard.	Yield (in boxes) in orchards of each specified size.			
	Under 6 acres.	6 to 10 acres.	11 to 20 acres.	Over 20 acres.
Clean tillage cultivated	262.6	224.2	206.9	190.1
Mulch crop	299.1	232.9	215.0	202.9
All orchards	280.9	227.7	210.7	196.5

As concerns the age of the trees, the orchards show a steady increase in yield up to 10 years, and thenceforward the yield per acre remains practically steady, barring fluctuations according to the season.

Another factor which influences the yield is the variety of fruit. Both Yellow Newtown and Esopus are trees which, comparatively speaking, come into bearing late in life. Soil, condition of tree, insect pests, diseases, pruning, thinning, etc., are other factors which have an influence on the yield of marketable fruit.

The average yield in Hood River Valley may show an increase in the next few years, due to the fact that irrigation and the use of mulch crops are coming into more general use. Mulch crops, when properly handled, add considerable humus to the soil. It can not be said conclusively that the mulch-crop system of management produces a larger yield in all cases, but the mulch-crop and irrigated orchards yielded 10 boxes per acre more than did those in clean cultivation and for the greater part unirrigated. Clean cultivation without the addition of humus of any kind, especially in the orchards without water, tends to deplete the soil. This is shown very conclusively by the condition and health of the trees on those orchards of bearing age which have been intensively cultivated for years without the addition of any plant food in the form of manure or a mulch crop.

MARKETING AND PRICES RECEIVED.

It is not the purpose of this investigation to follow the fruit farther than the loading station, and the costs here given are for the fruit delivered f. o. b. at Hood River station. The net prices which are returned to the grower are usually on this basis, all loading, freight, selling, and association charges being deducted.

The fruit in Hood River Valley has in general been handled by associations or distributing agencies. These may be either cooperative or otherwise, but most of the fruit has been shipped through cooperative organizations. Such organizations usually handle the fruit at a fixed cost per box, this being ordinarily 10 cents, or it may be handled on commission.

Hood River apples reach widely different markets, many of them entering the foreign trade. The grower does not hold the fruit in storage on his place, but it is often stored by the association, the grower being charged a fixed amount per box for storage.

The net prices returned to the grower vary greatly. Extra fancy bring the highest price, followed by the fancy, and then by C grade. It sometimes happens that a grower's returns are greater for lower grade fruit than for higher grade, there being sometimes a demand for the lower grade which makes its marketing more successful. Ordinarily, however, this is not the case, and the aim of growers is to produce the highest percentage possible of extra fancy fruit.

Because of the fact that Yellow Newtown and Esopus are the principal varieties of the valley, both being of high quality and commanding correspondingly high prices, the average price received has been somewhat in advance of that received in some other sections where a greater proportion of the lower priced varieties are grown. During the last few years prices have varied greatly. The returns received f. o. b. by the growers from whom figures were obtained averaged $1.11 per packed box for the years 1910 to 1914, inclusive. The averages by years are $1.52 for 1910, $1.41 for 1911, $0.77 for 1912, $1.23 for 1913, and $0.63 for 1914.

These variations in price are due to many factors. In years of very large yields the price is correspondingly low, while in years when there is a scarcity of fruit the price is high. In 1912 and 1914 the prices received for northwestern fruit were disastrously low, but the other years have helped to make up a fair average. The annual yields corresponding with the yearly prices were a third greater in 1912 and 1914 over that of the other years mentioned. The average price received was due not to the production in the orchards of the valley, but to the annual production in most apple regions of the country. In 1915 and 1916 good prices were received. It will be seen that the price received per box, averaged for a period of 5 years, is about $0.09 above the cost of production, all annual charges up to the time the fruit is delivered at the station being considered.

ORCHARD MANAGEMENT.

The orchards in Hood River Valley are in general well managed. The typical commercial orchard is run in a businesslike way. There are two distinct systems of management—the clean-cultural system and the shade-crop, or mulch-crop, system. All orchards using mulch crops are irrigated, but only about 27 per cent of the clean-cultural orchards are irrigated. Thus the two general divisions are the clean-cultivated and usually unirrigated, and the mulch-crop or irrigated orchards. There is more total labor connected with the mulch-crop system, but when the orchard is credited for the hay removed the net cost per acre for labor is somewhat less than in the clean-cultural system of management. Under orchard management will be discussed all those items pertaining to the growing and harvesting of the fruit. These items are manuring, pruning, disposal of brush, cultivation, handling mulch or shade crop, irrigating, propping, thinning, spraying, picking, hauling, sorting, packing, and all incidental labor in any way connected with growing or handling the crop.

MAINTENANCE LABOR.

MANURING.

The practice of applying manure is not general. Of the orchardists interviewed, 65 per cent apply manure to a greater or less extent, but the average amount of stock kept is small and as there are few dairy herds in the neighborhood, the amount of manure available for the orchard is very limited. A few orchardists haul manure from town, but on account of the long haul this is not generally done. The average grower will have about 15 to 20 tons of manure for his entire farm. He does not apply this evenly over his orchard, but puts it where it is most needed. It may all go on one or two acres, but the parts heavily manured probably will not receive another coat for several years. The manure is hauled out usually by one man and a team, using a sled or wagon, during the fall or early spring, or as the manure accumulates. It may be put in piles to be spread later, or spread as hauled out. It is usually worked or harrowed into the soil in the spring; if applied on a mulch crop, it is left until the latter is plowed under. In a few cases commercial fertilizers have been applied, but this is not common, and the growers usually do not believe it pays.

The orchardists using mulch crops do not manure to such an extent as those practicing the clean-culture system. Only 58 per cent of the former apply manure, as compared with 70 per cent of the latter, but those mulch-crop men who do apply manure put on more per acre. The quantity applied per acre averages for all records about 1½ tons, at a cost of $1.34 for labor, or a total cost of $3.56 per acre for labor and material.

PRUNING.

Winter pruning is the general practice in Hood River Valley, although considerable summer pruning is practiced on Esopus trees. Growers try to prune every year, although a great many prune only every other year. In some cases an orchard is pruned only once in three or four years. A few men were found who believed in very little pruning. The orchards during the greater part of their life have been without irrigation, and the trees have not made as rapid growth as those in many irrigated sections.

No particular method of pruning is practiced. It might be said that the open-head system is approached, as contrasted with the center-leader type of pruning. The trees are generally headed low and the branches hang low; thus in many orchards the trees have a "squatty" appearance. Generally they are set at such a distance and so pruned that there is sufficient light and air. The amount of propping required depends upon the habit of growth and shape of the tree, but thinning and harvesting are facilitated by heading the trees low.

The summer pruning consists usually in tipping the branches. According to the growers, the purpose is to induce more regular bearing and to give the trees a more stocky growth; however, there was not enough evidence to form any definite conclusions in regard to this. Many growers prune heavily one year and lightly the next. The average number of trees a man will prune a day in Hood River Valley, where winter pruning is practiced, is 30. The age of the trees apparently did not to any extent affect the time required, as Table VI will show.

Table VI.—*Influence of age on time and cost of pruning on farms studied.*

Age.	Trees pruned in 10 hours.	Hours of man labor per acre.	Cost of pruning.		
			Per acre.	Per tree.	Per box.
8 to 9 years	34	20.54	$4.62	$0.07	$0.0223
10 to 11 years	28	25.14	5.66	.08	.0275
12 to 13 years	29	24.45	5.50	.08	.0252
14 to 15 years	32	24.80	5.58	.07	.0170
17 years and over	32	22.38	5.04	.07	.0236
All records	30	24.36	5.48	.08	.0247

The size of the orhard, like age, has little effect on the time required for pruning. With the orchards arranged in five groups, according to size, is is found in each group to cost practically $0.08 per tree, or $0.025 per box.

Pruning time is influenced by the variety, style, and method of pruning, the system, whether alternate or annual, the amount of propping and thinning the grower may practice, the thrift of the tree, and peculiarities of individual trees. Taking all the orchards together, there was a man-hour charge for pruning of 24.36 hours, or $5.48 per acre. With 72 trees per acre, there is an annual charge of $0.08 per tree, or $0.0247 per box. The cost per box for pruning was practically the same for clean-cultural orchards and those under a mulch-crop system of management, it costing $5.28 per acre, or $0.024 per box, for the former and $5.74 per acre, or $0.025 per box, for the latter.

DISPOSAL OF BRUSH.

Three well-defined methods of disposing of the brush are practiced in this region. One way is to go through the orchard with a one-horse wagon or slip boat, pick up the brush, and haul it to some convenient place for burning. Another is to gather the brush into piles by hand, or, more commonly, by raking with a horserake or some homemade device, and to haul it out and burn it later. The third method, the one least practiced, is to use a brush burner in the orchard. There are several kinds of patented brush burners, but their use as yet is largely confined to younger orchards, many growers claiming that some injury to the trees has resulted from their use in the bearing orchards. A brush burner is a device which is drawn through the orchard and into which the brush is piled and burned. (See fig. 5.) It is a labor-saving device and may come into more general use if the liability of injurying the trees be overcome.

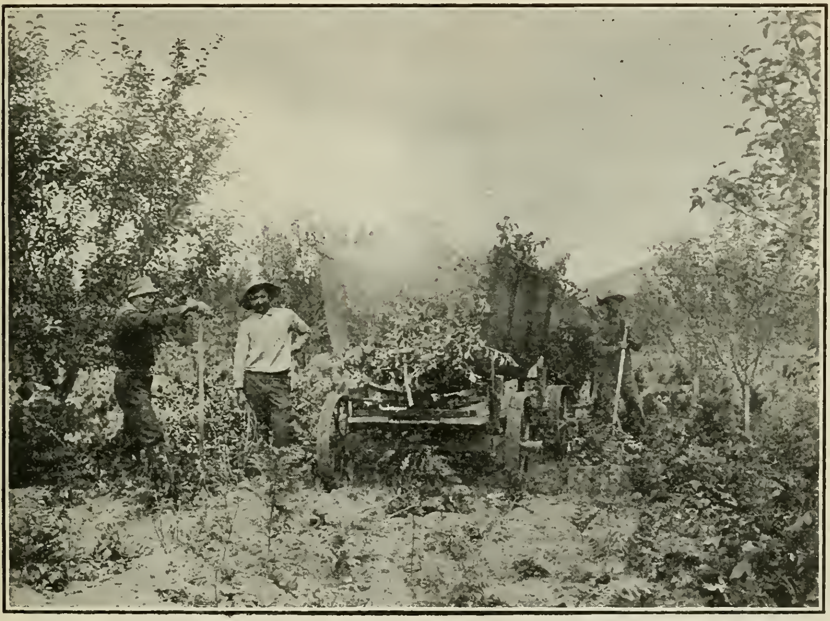


FIG. 5.—A portable brush burner in use during the summer pruning in the upper Hood River Valley. Such burners are not generally used in the older orchards.

The most common method of brush disposal is the one first mentioned above, in which the brush is gathered and hauled from the orchard in one operation. The abundance of wood for fuel makes it unnecessary to save the trimmings for firewood, as is done in many sections. The annual cost of disposing of the brush is $2.36 per acre, or $0.0106 per box, on the 54 orchards considered.

CULTIVATION AND SOIL MANAGEMENT.

Cultivation, which is the most expensive of all maintenance operations, is practiced to some extent in all of the orchards. Thirty, or 55½ per cent, of the men practice clean cultivation annually and use no mulch crop, while 24 use mulch crops and cultivate perhaps once in three years, or to some extent in early spring every year.

The practice of sowing the orchards to mulch crops is being adopted rapidly and at the present rate may in a few years become universal, providing sufficient water be available.

Clean cultivation was formerly practiced universally. The tendency to change to the mulch-crop system of management is especially noticeable in the older bearing orchards. This is as may be expected, for the older orchards show the need of humus and plant food.

Commencing with the spring treatment of the soil, plowing is frequently one of the first operations, although more often plowing

FIG. 6.—The disk in use on a clean-cultivated orchard.

is done in the fall. Exactly 50 per cent of the 54 growers practice plowing, the number being about evenly distributed between the clean-cultural and mulch-crop orchards. Those of the former who plow do so usually every year, while the latter plow only when the crop is turned under, or about once in three years. A 12-inch field plow, drawn by two horses, is the common type used, the furrows being from 6 to 8 inches deep midway between the tree rows and 3 to 4 inches deep close to the trees. Fall plowing is practiced most frequently in mulch-crop orchards.

The normal cost of plowing an acre in the cultivated orchards is $2.79 per acre for a man and team plowing 1.88 acres per day. In the case of mulch-crop orchards, the same crew will plow 1.61 acres per day at a cost of $3.26 per acre.

The orchardists of the lower valley begin to cultivate their orchards during the latter part of March or early in April. Following the plow the cultivating tool first used on the clean-culture orchards is usually the spring-tooth harrow, which puts the soil in good condition for succeeding cultivations. This harrow is run "both ways." In some cases the disk or the light drag harrow may be the first tool used, but in any case the soil is well worked up in the early spring. Following the first cultivation comes either a disk or a spring-tooth; these tools usually alternating with each other a few days apart.

FIG. 7.—A float, or leveler, in use. This implement is commonly used after a thorough cultivation to smooth over the soil and create a fine dust mulch.

(See fig. 6.) After three or four cultivations, a spike-tooth is commonly used. This serves to fine the soil and create a mulch. The ground is then often leveled down with a clod masher or float. (See fig. 7.) This completes the first spring cultivation, which is given as soon as the orchardist can get on the land. Other cultivations follow every few weeks, especially after rain occurs. Beginning about May 15, those who practice clean cultivation go over the ground about once every two weeks until the middle of July. These later harrowings are performed usually with weeders (see fig. 8) or with spike-tooth harrows. These tools are usually light, the aim being not to cultivate deep, but to keep a mulch on the soil and keep the orchard free from weeds. Each tool is often run "both ways," and frequently is zigzagged to form a "figure eight" about the trees.

Rilling the orchards for irrigation is discussed under "Irrigation," but is charged to cultivating time. In the case of the orchards under mulch crop, the crop is sown usually during the summer and is left down for a varying number of years. It is not necessary to reseed unless the orchard is plowed up and cultivated, thus killing the crop. The practice of turning the mulch crop under annually, common in the East, is not general here. When these orchards are plowed up

FIG. 8.—The common type of weeder used in cultivating. The driver rides, his weight helping to force the knives into the soil. The tips of the branches of the young trees are being sprayed for aphis.

and cultivated, about the same general system is followed as in the case of the orchards which are clean cultivated annually. Orchards in alfalfa usually are disked every spring; sometimes a spring-tooth also is used.

The average time required for the different operations in cultivation was in each instance more in the case of mulch-crop orchards than in those under the clean-culture system. As will be seen in Table VII, the cost of disking an acre once over is about the same for both types of management, but there is a difference of $0.18 per acre in the case of the spring-tooth, $0.03 per acre for the spike-tooth,

$0.25 per acre for the weeder, $0.18 per acre for the light-draft harrow, and $0.06 per acre for the float in favor of the clean-culture system.

TABLE VII.—*Normal time and costs of one cultivation on farms studied.*

Item.	Plow.	Disk.	Spring tooth.	Spike-tooth.	Weeder.	Light draft harrow.	Float.
Clean cultivated orchards:							
Man-hours	5.32	2.28	1.40	0.88	1.13	0.57	1.06
Horse-hours	10.64	4.56	2.80	1.76	2.26	1.14	2.12
Acres per day	1.88	4.39	7.14	11.36	8.85	17.54	9.43
Cost per acre	$2.79	$1.20	$0.74	$0.46	$0.59	$0.30	$0.56
Mulch-crop orchards:							
Man-hours	6.21	2.30	1.76	0.93	1.60	0.92	1.19
Horse-hours	12.42	4.60	3.52	1.86	3.20	1.84	2.38
Acres per day	1.61	4.35	5.68	10.75	6.25	10.87	8.40
Cost per acre	$3.26	$1.21	$0.92	$0.49	$0.84	$0.48	$0.62
All orchards:							
Man-hours	5.74	2.29	1.55	0.91	1.23	0.74	1.14
Horse-hours	11.48	4.58	3.10	1.82	2.46	1.48	2.28
Acres per day	1.74	4.37	6.45	10.99	8.13	13.51	8.77
Cost per acre	$3.01	$1.20	$0.81	$0.48	$0.65	$0.39	$0.60

Table VII serves to show normal times for the different kinds of tools of standard make and width. It was found that the average annual cost of cultivation, including plowing, is $11.74 in the case of the clean-culture orchards and $4.44 in the case of the mulch-crop orchards, which receive a thorough cultivation about once every three years.

TABLE VIII.—*Total cultivation costs for all records.*

Item.	Clean culture.		Mulch crop.		All records.	
	Per acre.	Per box.	Per acre.	Per box.	Per acre.	Per box.
Plowing	$1.10	$0.005	$0.70	$0.0031	$0.92	$0.0041
Other cultivation	10.64	.0488	3.74	.0164	7.57	.0341
All cultivation	11.74	.0538	4.44	.0195	8.49	.0381

As is shown in Table VIII, there is a difference in cost for all cultivating time of $7.30 per acre, or $0.034 per box, in the favor of the mulch-crop system, but this difference is largely offset by the cost of irrigating on the latter orchards.

MULCH CROPS.

There are two kinds of mulch or shade crops used in the valley, namely, clover and alfalfa. (See fig. 9.) They are usually sown alone, although in some cases the orchard may be in both clover and alfalfa. Of the 24 orchards in mulch crop, there are 12 in clover, 8 in alfalfa, and 4 in both clover and alfalfa. About 12 pounds of alfalfa are sown per acre and 14 pounds of clover. Usually the orchards do not need reseeding unless plowed up. Thus, the cost of seed is a small item when distributed over several seasons and is almost negligible in arriving at the cost per box.

Of the 24 growers, 18, or about 75 per cent, make a practice of taking some hay from their orchards. One grower pastures his orchard, and four others mow the hay and leave it on the ground as a mulch. The number of cuttings made varies from one to three. The average yield of hay per acre on those orchards from which hay is cut is 1.5 tons for those in clover and 1.6 tons for those in alfalfa. These are actual yields for the years when hay is cut, but

FIG. 9.—A 13-year-old Newtown orchard under cover-crop system of management. Note the clover grown between the trees and the irrigation furrows.

when it is distributed over all years, including those when no hay is cut, the yield is 0.86 ton per acre for the clover and 1.54 tons for the alfalfa. Thus it is evident that the alfalfa orchards are not turned under nearly so often as those in clover.

The cost per ton of harvesting this hay is the same in both cases. In harvesting hay a man and team with mowing machine are usually used for cutting the hay between the rows and a scythe used for mowing out the tree rows. It is raked either by hand or by horse-rake and when cured is usually drawn in on a sled, as it is much easier to load a sled than a wagon in the orchard. The cost of harvesting is no doubt higher per ton than would be the case in an open field.

TABLE IX.—*Labor yields, and credits for mulch or shade crops for the growers who harvest hay.*

Item.	Clover.	Alfalfa.	Mixed.	All mulch crops.
Number of records	9	6	3	18
Labor per acre:				
Man-hours	8.50	14.92	12.71	11.34
Horse-hours	7.44	13.74	10.94	10.13
Cost of harvesting:				
Per acre	$3.03	$5.42	$4.50	$4.07
Per ton	$3.52	$3.52	$3.10	$3.42
Yield per acre (tons):				
Actual	1.51	1.59	1.47	1.53
Minimum	.60	.80	.67	.60
Maximum	3.00	3.00	3.00	3.00
Distributed [1]	.86	1.54	1.45	1.19
Total credit per acre	$9.24	$16.31	$15.75	$12.68
Net credit per acre	$6.21	$10.89	$11.25	$8.61

[1] Distributed over all years, including those when no hay is cut.

Credit from mulch crop.—The gross credit per acre for hay harvested amounts to $9.24 for the clover orchards and $16.31 for those in alfalfa, Taking out the labor cost of harvesting, there is a net credit of $6.21 for clover and $10.89 for alfalfa. Taking into consideration all mulch crops cut for hay there is a total credit of $12.68 for hay, or a net credit over harvesting labor of $8.61.

There is a growing tendency to pasture hogs on these mulch-crop orchards, and many growers are now raising pigs, so that pasturing may eventually become quite general. Five of the mulch-crop orchardists take no hay off, but cut it and leave it on the ground in the form of green manure, which no doubt pays as well in the long run as removing the hay. This practice should materially increase the yield of fruit.

When the 24 records under this system of management are all considered, whether hay is taken off or not, there is found to be an annual charge of $3.41 per acre for labor put on the mulch crop in cutting or harvesting it and an annual total credit of $9.59 per acre, or a net credit of $6.18 per acre.

Clean culture versus mulch or shade crops.—There seems no doubt that the practice of clean cultivation without the addition of humus or plant food by means of some kind of mulch crop soon will be wholly discontinued. There are several very apparent reasons brought out in the study of these 54 farms why the mulch-crop method of management is much the better. If figures are left wholly out of consideration the mere condition and appearance of the orchards would warrant this conclusion. (See fig. 10.) The bearing orchards under the clean-cultural system often show a decided discoloring and early maturity of foliage. This is most noticeable when the orchard tracts of the valley are viewed from one of the distant hills. One can invariably pick out the orchards under the two kinds of soil management by the appearance of the foliage, that of the intensively clean cultivated orchards often having a light yellowish appearance. Lack of irrigation of course has much to do with this difference, but even irrigation without the addition of humus will not long give color and health to a bearing orchard. The older the orchard, the more noticeable is the difference in the physical condition of the trees under the two systems of management.

The average soil of the valley is of such a type that it becomes nonproductive after excessive cultivation. This is one reason why the use of a mulch crop shows results. The costs also show an advantage

FIG. 10.—A clean-cultivated orchard which has never been irrigated. The trees are Esopus and Newtown and are in need of humus or nitrogen.

in favor of the mulch crop. The maintenance labor is $43.63 per acre, or $0.2001 per box, for the 30 clean-culture orchards. The net labor cost in the case of the 24 mulch-crop orchards is $35.41 per acre, or $0.1554 per box. Thus there is a difference in maintenance labor of $8.22 per acre, or $0.0447 per box in favor of the mulch-crop system. Also yields are higher under the mulch-crop system, and the orchard is more healthy and has a better appearance generally. These advantages will undoubtedly become more and more apparent as the system becomes better established in these orchards and has more time to show results. In considering the farms studied it would seem best not to leave the crop down too long, but to turn it under occasionally. The advantage of the mulch-crop system over the clean-cultural apparent here may or may not hold good in other sections. It depends entirely on whether or not the soil can be kept from being depleted and the trees in good health by natural soil fertility.

IRRIGATION.

Irrigation has become general in the valley only during the last 5 years and mostly within the last 3 years, and is rapidly extending. With the practice of irrigation has come an effort to restore nitrogen to the soil by the aid of clover and other legumes. Both irrigation and the practice of sowing legumes are confined largely to the old

FIG. 11.—An irrigation lateral in the Oak Grove district of Hood River Valley.

orchards, it not being thought necessary, in most cases, to irrigate a young orchard not yet in bearing.

The growers of the lower valley are served by three main irrigation ditches. Those on the east side of the river, including practically all the men whose records figure in this investigation, receive water from the East Fork irrigation ditch, while those on the west side receive water from the Hood River irrigation district canal and the Farmers' Irrigating Co. canal. The East Fork and the Hood River irrigation ditches are in bonded districts, while the Farmers' Irrigating Co. is not. The East Fork company, organized in 1895, was operated as a stock company of farmers until 1913, when the district was bonded. In 1914 the rate per acre under the ditch was $1.24, while for 1915 it was $2.50 per acre. Previous to this the rate was from $5 to $8 per miner's inch, the farmer buying as much water as he desired. There is an area of over 13,000 acres under this ditch. (See fig. 11.)

The water is usually turned on from the 1st to the 15th of June. The orchards are ordinarily rilled out for irrigation. Some growers prefer to flood their orchards, but this is not a general or popular practice. As yet the irrigation system is far from being universally satisfactory. As in many other places, it takes time to adjust conditions when changing from a dry-land system of farming to one of irrigation. Prior to the time the ditch was bonded those not

FIG. 12.—One method of irrigation followed in the lower valley. This is a temporary lateral and rills are made at right angles to it. This is not the common method.

holding stock received no water unless they used waste water, which was always uncertain.

Twenty-seven per cent of the clean-cultivated orchards and 100 per cent of those under mulch crops are irrigated.

Creasing, or rilling out, is a general practice in the clean-culture orchards. Usually about two irrigations are made on these orchards, the first coming about the latter part of June and the second about the 1st of August. Rilling is not generally practiced in the mulch-crop orchards, the soil being creased but once after sowing. Creasing is usually done with homemade drags, or " rillers." Four, five, or more furrows ordinarily are made at a time, at an average distance of 30 inches apart. The bottoms of these rillers are rounded off so as to make smooth creases. The drags are usually drawn by two horses.

Mulch crops are often irrigated by flooding. The water is conducted from the main ditch through the orchards either in wooden flumes or in open ditches. In a few cases piping has been installed. The main laterals through the orchard are run along the higher ridges or along the more elevated side of the orchard tract. If flumes are used, the water is let out through holes placed at intervals in the side of the flume; if in open laterals, at the same intervals by means of openings made with a hoe. The water then seeks its own course over a strip usually only a few tree rows wide, following more or less the rills made at the time the mulch crop was sown. This practice keeps water on some part of the orchard for the greater part of the summer months. In many cases the grower finishes each irrigation of his orchard tract just about in time to begin irrigating again. (See fig. 12.)

TABLE X.—*Time and cost of irrigation of farms studied (Hood River Valley).*

Type of orchard.	Per cent of orchards irrigated.	Average number of irrigations.	Man-hours per acre.		Cost pro rata.[1]		
			Number.	Cost.	Labor.	Water.	Total.
Clean cultivated	26.67	2.38	11.86	$2.67	$0.71	$0.71	$1.42
Mulch crop	100.00	3.38	29.60	6.66	6.66	2.62	9.28
All orchards	59.26	3.13	25.16	5.66	3.35	1.56	4.91

[1] Cost pro-rated over irrigated and nonirrigated orchards.

The yield per acre of the 8 clean-culture orchards under irrigation is 257 packed boxes, as compared with 203 packed boxes for the 22 orchards not irrigated, with a total cost per box of $0.98 for the former and $1.045 for the latter. However, the orchards which were irrigated average about 4 acres less in area, which partly accounts for the greater yield.

Orchards set fruit well and grow well under natural conditions, but the fruit does not often attain its best size without irrigation.

The labor cost of irrigating is $2.67 per acre for those orchards in clean cultivation which practice it and $6.66 for those in mulch crop. Considering the 54 records, there is an average annual acre charge for labor in irrigation of $3.35, or $0.0151 per box.

THINNING.

Thinning is practiced by all growers in the valley. Some thinning is usually done each year and is practiced for several reasons, but chiefly to improve the size and quality of the fruit remaining on the tree. Men differ widely in their ideas on thinning. There is no doubt that systematic thinning greatly increases the size and quality of the remaining fruit, and the quantity of marketable fruit is invariably increased. The belief prevails and results apparently show that annual thinning tends to produce more even and more certain annual crops. (See fig. 13.)

Thinning involves considerable labor. Women are sometimes employed for this operation, the work being performed usually by the operator and the members of his family, but sometimes by hired laborers. Only white labor is intrusted with this work. Most often only clusters are thinned, leaving one or two apples in a cluster.

FIG. 13.—Thinning Newtown apples. The cost of thinning in Hood Valley is as great as the cost of pruning.

This is particularly true of the Yellow Newtown. The operation is performed largely from ladders with thinning shears.

Most of the thinning is done early in the summer, since thus the remaining apples make a better growth and at the same time the tree itself remains in better physical condition than when the thinning is done later, thereby insuring a more regular and uniform crop each year.

The area of the orchard has some influence on the time per acre devoted to thinning. In the case of orchards under 5 acres in area the difference in time is very marked (see Table XI.) Small acreages are usually more intensively managed as regards thinning, as well as in many other respects.

TABLE XI.—*Relation of area of orchard on farms studied to time devoted to thinning.*

Size of orchard.	Number of orchards.	Man hours per acre.	Cost.		
			Per acre.	Per tree.	Per box.
Under 6 acres	4	44.75	$10.07	$0.13	$0.0358
6 to 10 acres	25	24.57	5.53	.08	.0243
11 to 15 acres	11	22.25	5.01	.07	.0221
Over 15 acres	14	20.87	4.70	.07	.0244
All orchards	54	24.63	5.54	.08	.0250

There is abundant evidence that it pays to thin the fruit and do it well. Not only is the yield of marketable fruit increased, but its quality is greatly improved, thus giving a high percentage of extra fancy fruit which brings correspondingly high returns. The average annual time consumed in thinning on the 54 orchards is 24.63 hours per acre, at a cost of $5.54 per acre, $0.08 per tree, and $0.025 per box. It should be borne in mind that this is an average cost. Where a tree is well loaded with fruit the cost of thinning may reach $0.25 or more per tree, but the cost per box will tend to be lowered.

PROPPING.

Propping the trees to prevent the limbs from breaking under the weight of fruit is a practice followed by all growers. (See fig. 14.) The labor for propping on the farms studied amounts to practically the same as that for pruning. Several methods of propping are practiced; first, that of propping the trees with notched or cleated boards; and, second, that of "tying up" the limbs of the trees, eliminating the use of board props. In tying, some growers use the "maypole prop," from the top of which wires or strings are strung and tied to the limbs requiring support. In many cases, however, the tying is done from limb to limb.

The material used in making the board props is often 1 by 2 inches or 1 by 3 inches, varying in length from 8 to 14 feet. Double-ply jute twine, costing about 10 cents a pound, is used in tying. Wire, also used for this purpose, is much more expensive, but lasts a correspondingly longer time. The labor connected with tying up the limbs is considerable; indeed, it is often a very expensive operation.

Board props are usually set during July. The orchardist generally hauls them out with a wagon and two horses, setting them as he hauls. Sometimes they are distributed to be set later. Where the limbs are tied to the props additional labor is entailed. Props have to be tended and reset from time to time during the summer and taken down and hauled in in the fall. On account of the variation in the methods of propping and the small number of orchardists who followed any one method, no segregation in time is made, the average propping time being calculated without regard to the practice followed.

The average amount of labor for propping, all records considered, is 14.23 man-hours and 13.56 horse-hours per acre, at an annual cost of $5.65 per acre, $0.08 per tree, and $0.0255 per box.

The average cost per acre on these farms is almost exactly the same for each of the three operations of pruning, thinning, and propping. (See Table XII.)

FIG. 14.—Trees propped to prevent breaking. This orchard is also heavily thinned every year. The varieties are Newtown and Esopus, in full bearing.

TABLE XII.—*Comparison of pruning, thinning, and propping costs (54 farms).*

Operation.	Number of orchards.	Cost.		
		Per acre.	Per tree.	Per box.
Pruning	54	$5.48	$0.08	$0.0247
Thinning	54	5.54	.08	.0250
Propping	54	5.65	.08	.0255

SPRAYING.

Spraying the orchards for diseases and insect pests is a universal practice in the valley, representing considerable labor and cash outlay for the average Hood River grower. On the 54 farms the average spraying-labor cost is \$8.83 per acre, or \$0.0398 per box. The cost of materials for spraying is \$8.69 per acre, or \$0.0391 per box, a total cost for labor and material of \$0.0789 per box. The use of the spray rig is a separate expense included under equipment charges. Forty-three growers own their own power-spray outfits, while 11 hire their spraying done. A number of steam spray outfits are still in use in the valley, but these are being replaced by gasoline power sprayers. The average size spray tank holds about 150 gallons, the size varying from 100 to 250 gallons. The pressure maintained in spraying varies from 150 to 225 pounds.

In spraying two or three men are commonly employed. When three men are used, which is the practice of 57 per cent of the growers, one man drives the team and tends the engine, while the other two handle the lines of hose. In nearly all cases two lines of hose about 50 feet long are used. A spray rod is attached to each hose. Where two men are used, as on practically 40 per cent of the farms, both hold spray rods.

The average length of spray rod is 10 feet, although a few 12-foot rods are used in the older orchards. The rods are usually bamboo over aluminum tubing. Spray towers are not used except in very few instances, the practice differing in this respect from that of many growers in the East. The trees are of a low habit of growth, so that ordinarily it is not necessary to use a tower in order to spray the top of the tree thoroughly.

The average crew of two men and a team, or three men and team, sprays about 5½ acres a day and applies from 1,100 to 1.500 gallons of material in this time. There is no appreciable difference in time between a 2–2 crew and a 3–2 crew, the extra man employed being the driver, two leads of hose being used in each instance. Two rows of trees are sprayed at a time, one lead of hose being used for each row.

The principal diseases which it is necessary to control in Hood River Valley are apple scab, apple powdery mildew, and anthracnose. The principal insect pests are San Jose scale, leaf roller, aphis, blister mite, and coddling moth.

Where a spray rig is hired, the usual rate paid is \$1 per hour for man, rig, and team. Only the regular rate is here figured for the labor, leaving 47½ cents per hour for the use of the rig itself. This charge of 47½ cents is included in the fixed charges with depreciation and upkeep, in order to make the cost items comparable with those on farms having their own spray outfits.

TABLE XIII.—*Comparative efficiency of hired and of owned spray rigs on farms studied.*

Ownership of rig.	Number records.	Average number of sprays.	Total man-hours per acre.	Total horse-hours per acre.	Acres in 10 hours.	Gallons in 10 hours.	Total gallons per acre for all sprays.	Total gallons per tree for all sprays.	Cost per acre.			Cost per box.
									Labor.	Material.	Total.	
Own	43	5.7	26.39	20.99	5.38	1,172.14	1,241.81	17.31	9.09	8.71	17.80	0.0789
Hire	11	5.1	23.00	17.59	5.91	1,395.11	1,203.89	16.81	7.81	8.69	16.50	.0791
Own and hire	54	5.6	25.70	20.30	5.47	1,205.42	1,234.09	17.21	8.83	8.71	17.54	.0790

The comparative efficiency of the owned and hired rigs is shown in Table XIII. The average number of sprays is 5.7 for the owned and 5.1 for the hired rigs. As would be expected, there are fewer man and horse hours per acre in the latter case. It is seen that those who own rigs spray an average of 5.38 acres in 10 hours, applying 1,172 gallons of material, while hired rigs spray 5.91 acres, applying 1,395 gallons in 10 hours. Thus, although the labor cost per acre is less in the case of the hired rigs, the total material cost is nearly the same. The cost of labor and material for the owned rigs is $17.80 per acre, while for the hired it is $16.50 per acre. It would seem therefore that so far as the actual labor and material cost of spraying is concerned, it makes little difference whether the rig is owned or hired.

Because of the effect of climatic conditions upon spraying, no well-defined spraying schedule is followed in the valley. Most growers have their own ideas about spraying. Some troubles, particularly apple scab, are very hard to control, and spraying is as yet in somewhat of an experimental stage here.

This region differs from most others in that a great many different kinds of sprays are made of varying strength. The first spray applied in the spring is usually a lime-sulphur dormant spray, which is applied ordinarily in March. This, often called the "clean up" spray, is made primarily to control the San Jose scale. The strength of this spray is usually 1–10, that is, 1 gallon of commercial lime-sulphur to 10 gallons of solution. Usually a single nozzle and a coarse spray are used, with a pressure of about 175 pounds. Practically 90 per cent of the growers make a practice of using this spray, and make but one application of it during a season. Man-hours per acre for this spray average 4.74 and the horse-hours 3.72. The average acreage for all crews is 5.38 acres per day. The labor cost per acre is $1.62, material cost $2.45, making a total of $4.07 per acre. If this spraying cost is distributed over all the orchards the cost is found to be $3.55 for material and labor, or 20 per cent of the total spraying costs on all the orchards considered.

A later dormant spray is now being advocated for killing the leaf roller and aphis eggs. It is made with a soluble oil or miscible oil, diluted and mixed with water at the rate of about 3 gallons of oil to each 50 gallons of spray mixture. In applying this, high pressure is used, and the spray is driven against the branches with great force. The nozzles are held close, so as to cover thoroughly the terminal buds, fruit spurs, and smaller limbs. Large-chamber type mist nozzles are used for this purpose. This spray is not generally practiced as yet, but it is increasing in favor.

The second regular spray is generally applied about the time the fruit buds are showing pink and is known as the "pink spray." In the lower valley it is made around April 20. This is applied primarily as a preventive against apple scab. A 33° Baumé (25 per cent sulphur in solution) lime and sulphur solution, mixed at the rate of 1–25, or 2 gallons of the solution to each 50 gallons of spray, is the strength generally used. This spray, used by about 50 per cent of the growers, is applied very thoroughly. The aim is to cover the entire surface of the tree, paying particular attention to the leaf buds and expanding fruit buds. The average time in applying the pink spray, together with other lime-sulphur sprays which may be later applied without lead, is 4.13 man-hours and 3.39 horse-hours per acre, or an average of 5.9 acres per day. About 1,300 gallons of material is used in 10 hours. The labor cost of $1.44 and a material cost of $0.97 make a total of $2.41 per application. The cost of all lime-sulphur diluted sprays applied for scab (in combination with no other material) is $1.39 per acre, or about 8 per cent of the total cost for spraying for all orchards.

The third regular spray, and perhaps the most important of all, is the calyx, or first arsenate of lead spray, coming about May 10, when about 90 per cent of the petals have fallen. This spray is applied so as to place the poison well into the calyx cup, for the control of the codling-moth larva. A fungicide is ordinarily used at this time, in order to cover the foliage and forming fruit as a preventive for apple scab. The "calyx spray" is made by all orchardists of the valley, although there is some variation in the kind and quantities of spray materials used.

A common mixture used by about two-thirds of the growers is made of 1 gallon of lime-sulphur and 2 pounds of paste lead arsenate to 50 gallons of spray mixture. A few use only lead arsenate and water at the rate of about 2 pounds of lead arsenate to 50 gallons of water. For the most part those who use no lime-sulphur use a

Bordeaux 4–4–50 solution—that is, 4 pounds of lime, 4 pounds of blue vitriol, and 50 gallons of water. The lead arsenate is used the same strength as above. In all cases growers use arsenate of lead in this spray for the control of the codling-moth larva, although some omit the other ingredients. Where either Bordeaux or lime-sulphur is used it is for the control of apple scab. Some growers now make a practice of using about 3 pounds of atomic sulphur to 50 gallons of spray mixture for apple powdery mildew, and apply it in combination with the calyx spray.

Whatever mixture is used, the number of acres sprayed per day is between 5 and 6. Cost for labor is $1.47 per acre for diluted lime-sulphur and lead-arsenate spray, $1.50 for Bordeaux and lead arsenate, and $1.54 for lead-arsenate spray alone. The material cost for these sprays is $1.48, $2.41, and $0.75, respectively, or a total labor and material cost of $2.95, $3.91, and $2.29. (See Table XIV.) The lead arsenate and water spray is thus the cheapest, followed by the lime-sulphur and lead arsenate, and, lastly, the Bordeaux and lead arsenate, which is much the most expensive. In this calyx spray the most popular and, judging by the number using it, evidently the most effective combination is the lime-sulphur and lead-arsenate spray. If mildew is troublesome, atomic sulphur may be added.

The next lead-arsenate spray follows the calyx application in about 10 days. It is made by only a part of the growers. If the weather is favorable to apple scab, lime-sulphur, diluted 1 to 40 or 1 to 50, or atomic sulphur, 5 pounds to 50 gallons, is often added to this lead-arsenate spray. Some growers do not put lead arsenate in this spray, but use only the lime-sulphur or atomic sulphur.

The "thirty-day" spray is usually the second and a very essential spray for the control of codling moth. This occurs about 30 days after the calyx spray, hence its name. Lead arsenate at the rate of 2 pounds to 50 gallons is used. Atomic sulphur may be added at the rate of 5 or 6 pounds to 50 gallons for scab and mildew control.

Other sprays for scab control are sometimes applied if the weather continues wet, and ordinarily the third and last lead-arsenate spray for the codling moth is applied about the 1st of August. However, there may be an intervening codling-moth spray between the thirty-day spray and the final spray for the moth. In this spray lead arsenate is applied at the usual rate of 2 pounds to 50 gallons of water. Bordeaux 4–4–50 may be combined with this as a further protection against scab. In many of these sprays, particularly the early ones, a nicotine solution is often added for the control of the aphis, at the rate of about 1½ pints to 200 gallons of spray mixture.

TABLE XIV.—*Spraying practices (54 farms).*

Item.	Lime-sulphur, dormant.	Lime-sulphur diluted, not dormant.	Lime-sulphur diluted and lead arsenate.	Lead arsenate.	Bordeaux and lead arsenate.	Fall [1] Bordeaux.	Other sprays.	Total of all sprays.
Number of growers using	47	27	36	42	9	42	1	54
Average number of sprays	1	1.15	1.81	2.26	1.56	1.24	1	5.65
Number using 3-2 crew	28	13	19	24	7	22	1	31
Number using 2-2 crew	17	12	16	16	1	18	0	21
Number using other crews	2	2	1	2	1	2	0	2
Averages per spray:								
Man-hours	4.74	4.13	4.29	4.49	4.31	5.06	8.57	4.55
Horse-hours	3.72	3.39	3.38	3.51	3.54	3.99	5.71	3.59
Labor cost	$1.62	$1.44	$1.47	$1.54	$1.50	$1.74	$2.78	$1.56
Material cost	2.45	.97	1.48	.75	2.41	2.28	4.41	1.54
Total cost	4.07	2.41	2.95	2.29	3.91	4.02	7.19	3.10
Total cost of spraying per orchard using sprays	4.07	2.77	5.33	5.19	6.08	4.98	7.19	17.54
Average total cost of spraying for all orchards studied	3.55	1.39	3.55	4.03	1.02	3.87	.13	17.54
Percentage of total spraying costs	20.24	7.92	20.24	22.98	5.82	22.06	.74	100.00

[1] Of these 42 growers making a fall Bordeaux spray for anthracnose, 10 made an additional spray during the summer with Bordeaux alone for apple scab control, using a strength of 4–4–50 as compared to a 6–6–50 strength for the fall spray.

As a general rule a final spray is applied in the fall for anthracnose. Nearly 78 per cent of the growers use this spray. It is a dormant spray, applied after harvesting the fruit, and is made with a 6–6–50 mixture of Bordeaux. It often takes a little longer to apply than the other dormant sprays or the lead arsenate spray, because of the time required for mixing the ingredients.

In Table XIV spraying practices are summarized. On account of the great number of different practices followed in spraying, no attempt has been made to arrange this table according to the time of application. The average number of sprays of all kinds used for all orchards is 5.65, and the total cost for material and labor for these sprays is $17.54 per acre, or practically $0.08 per box.

MISCELLANEOUS.

There are many items of orchard labor which may be classified as miscellaneous. Summer pruning is included in miscellaneous labor, as are all such items as doctoring trees, painting wounds, care of lateral ditches for the orchard not included in irrigating time, and any other odd items which may appear. For these miscellaneous items there was found to be a labor cost of $2.03 per acre for the clean-cultural orchards, $1.17 per acre for those under the mulch-crop system, or $1.65 per acre for all orchards. The cost per box was $0.0074.

TOTAL MAINTENANCE COST.

Considering all items pertaining to the maintenance of the orchard in the 30 clean-cultural orchards there is found to be a total of 133.75 man-hours and 90.28 horse-hours per acre, at a net labor cost for maintenance of $43.63 per acre, or $0.20 per box. In the case of the 24 mulch-crop orchards there are 152.75 man-hours and 70.82 horse-hours for annual maintenance, with a cost of $45 per acre, or $0.197 per box. When both kinds of orchards are considered, there are 142.19 man-hours and 81.63 horse-hours, with a total maintenance labor cost per acre of $39.97, or $0.18 per box. This is 47 per cent of all labor cost, and 17.6 per cent of the total cost of production.

HANDLING THE CROP.

The labor cost of handling the crop is the largest of all labor costs, and since it is necessary to handle the fruit in a comparatively short time the cash expense for harvest labor represents the largest cash expense of the season. The handling cost includes picking, hauling shooks to the ranch, hauling out empty boxes from the packing shed to the orchard, and hauling in full loose boxes of fruit to the packing house. It also includes labor in the packing house, sorting, packing, nailing, and stamping, waiting on the packers, foreman, trucker, or any other extra packing-house labor. The last labor item of handling is hauling the packed boxes to the station. This handling or harvesting cost makes up 59 per cent of the total labor cost, or 22 per cent of the total annual cost of production. The handling cost per box was found to be very uniform and varied but little except as affected by yields and acre costs.

PICKING.

Harvesting the fruit from the trees is done by hand, either from the ground or from ladders. Ten-foot stepladders, costing from 25 to 50 cents per foot, are most common in use. Picking pails and bags of various description are used. These picking bags or buckets hold about one-half bushel and usually empty from the bottom. Two usually fill a picking box. The boxes are not filled so full as to prevent one being placed on top of another in hauling them in.

Picking ordinarily begins late in August with the Gravenstein and ends with the Yellow Newtown and Ben Davis late in October. As over 80 per cent of the output of the valley is Yellow Newtown and Esopus, most of the harvesting comes during the month of October. The labor is usually hired by the day. In a few cases men hire pickers by piecework; that is, the picker is paid so much per box. Day labor, however, is generally more satisfactory, as the apples are more carefully handled than when picked by the box.

Several factors influence the time required in picking, such as the variety, the age and size of the tree, and the condition of the fruit. The average time for all growers, with an average yield of 222 packed boxes, is 56 hours per acre, at a cost of $12.63, a cost per loose box of $0.0379 and per packed box of $0.0569, or nearly 6 cents per box.

TABLE XV.—*Influence of size of orchard on picking time (54 farms, Hood River Valley).*

Size of orchard.	Number orchards.	Boxes per acre.	Loose boxes in 10 hours per man.	Cost per acre.	Cost per packed box.	Cost per loose box.
Under 6 acres	4	280.9	59.8	$15.85	$0.0564	$0.0376
6 to 10 acres	25	227.7	59.5	12.91	.0567	.0378
11 to 20 acres	19	211	59.1	12.05	.0571	.0381
Over 20 acres	6	196.5	59.4	11.17	.0568	.0379
All records	54	222	59.4	12.63	.0569	.0379

The size of orchard and the yield per acre are two factors which would be expected to influence time required in picking. However, in the case of the farms studied this is not borne out by results, which show a remarkable uniformity in cost per box regardless of size of orchard or of yield. Table XV shows the cost of picking according to size of orchard, and Table XVI shows time and cost according to yield. It should be stated here, however, that the yield per acre would undoubtedly have affected the picking cost if the trees in general had been large, entailing much shifting of the ladders. This was noted in individual cases too scattering to materially affect the averages.

TABLE XVI.—*Influence of yield on picking time and costs (54 farms.)*

Yield (packed boxes).	Number of orchards.	Boxes per acre.	Boxes in 10 hours per man.	Cost per acre.	Cost per packed box.
150 boxes and under	11	115.0	58.1	$6.68	$0.0581
151 to 200 boxes	10	177.6	68.0	8.82	.0497
201 to 250 boxes	17	219.6	63.6	11.66	.0531
251 to 300 boxes	7	270.0	53.7	16.97	.0629
301 to 400 boxes	6	335.2	57.3	19.78	.0590
Over 400	3	440.8	52.7	28.24	.0641
All records	54	222.0	59.4	12.63	.0569

These tables show averages for hired pickers working by the day. They would show different results if piecework were under consideration. There is no doubt that the average picker can pick more boxes per day in heavily loaded orchards than in those with a light yield. The fact that they do not when hired by the day may be attributed largely to the fact that day labor considers a certain number of boxes as a fair day's work. They will pick a reasonable number in any case, working faster or slower according to the yield, but actually picking few more per day in one case than in the other. This, of course, does not apply to men who do their own picking or to other help personally interested in an orchard.

HAULING.

There are four hauling operations, namely, hauling the loose box shooks from the station to the ranch to be made up, hauling the empty boxes to the orchard, hauling the full picking boxes to the packing house, and hauling the packed boxes to the loading station. In hauling shooks, in the case of the farms studied, one man and team will haul an average load of 433 box shooks 2.01 miles at a cost of $0.004 per box shook, or $0.002 per box shook per mile. In many cases the box shooks are delivered at the farm, the price of delivery usually being from one-quarter to one-half cent per box. Taking all cases the cost per acre for getting the box shooks to the farm, including the contract labor, is $0.83 per acre, or $0.0037 per box. The box shooks are usually hauled during the late summer, early enough to give the grower time to make up his boxes. Hauling the loose boxes to the orchard from the shed, or wherever they are made up, is comparatively inexpensive, as they may be stacked on a sled or wagon and many of them hauled out at once. The most common practice is to combine hauling out the empty boxes with hauling in the full boxes. For those who make a separate operation of hauling out the empty boxes the cost per box averages about one-half cent. In hauling in the full boxes, where no hauling-out time is considered, it is found that a man and a team, with a wagon or truck, will haul 42 loose boxes per load, at a cost of $0.015 per packed box. When both hauling out and in are considered the cost is $3.59 per acre, or $0.016 per packed box. Either one or two men may work at hauling the full loose boxes to the shed. Where there are enough pickers to keep the haulers busy, two men can do this work to better advantage than one. This hauling is done almost entirely on the low truck wagon. (See Table XVII.)

TABLE XVII.—*Average time required for hauling on farms studied when man and team are used.*

Item.	Man-hours per acre.	Horse-hours per acre.	Cost per acre.	Size of load.	Cost per packed box.	Number of miles.	Cost per box per mile.
				Boxes.			
Haul shooks	1.80	3.35	$0.91	433	$0.0041	2.01	$0.002
Haul in full boxes	7.05	12.82	3.51	42	.0152		
Haul to station	11.73	23.46	6.16	87	.0285	4.00	.007

The most expensive of all hauling operations is delivering the apples at the shipping station. A man and team haul on the average 87 boxes per load 4 miles, at a cost of $0.0285 per box for the average distance hauled, or $0.007 per box per mile. There is considerable contract hauling, while many boxes are shipped to the association at Hood River via the Mount Hood Railroad at a freight cost in the lower valley from 2½ cents to 3½ cents per box. Considering all records, the total cost of delivering these apples f. o. b. at Hood River station is materially increased by this freight charge, making a total cost of $8.28 per acre or $0.0373 per box. The total cost of all hauling for the 54 farms, including the shooks, loose boxes in the orchard, and hauling to the station, including contract hauling, is $12.70 per acre, or $0.0572 per packed box.

PACKING-HOUSE LABOR.

Labor in the packing house includes sorting, packing, nailing, stamping, waiting on the packers, foreman, and any other labor employed about the packing shed. The cost of making the box is not included here, but under the cost of made-up box. This labor, when all records are considered, amounts to $0.1073 per box, or about 50 per cent of all handling labor costs, and 28 per cent of the total labor cost.

TABLE XVIII.—*Packing house averages and practices on farms studied.*

Operation.	Number practicing.	Per cent practicing.	Man-hours per acre.	Packed boxes in 10 hours per man.	Cost per acre.	Cost per packed box.	Pro rata cost per box.
Packing	53	98.15	29.03	77.5	$10.24	$0.0457	$0.0453
Sorting	32	59.26	43.62	53.3	9.81	.0463	.0262
Machine sizer	21	38.89	34.31	82	7.72	.0320	.0135
Nailing	14	25.93	10.20	232	2.30	.0108	.0027
Nail and wait	40	74.07	14.13	200	3.18	.0141	.0106
Foreman	16	29.63	13.28	213.4	2.99	.0121	.0040
Waiting	6	11.11	11.31	260	2.54	.0096	.0013
Other packing labor	6	11.11	33.03	95	7.41	.0357	.0037
Total cost per box							.1073

Table XVIII shows the packing-house practices, indicating the number who practice the different operations, together with the average time and costs per acre and per box. The pro rata column is the cost per box distributed over all the records, so that the total column represents the actual packing-house cost for the 54 records.

Sorting.—All apples are sorted and packed in the packing shed or tent. There are two methods of sorting. The apples may be sorted either by hand or on the sorting tables of a sizing maching. Previous to the introduction of the sizing machine many apples were sorted and packed by women. Usually on the larger ranches men are now employed in the packing house.

The crew in the packing house will vary with the size and condition of the crop. It is usually necessary to have more sorters than packers. Often four sorters are necessary to keep three packers busy.

Many growers use a mechanical sizer and claim that much time and expense is saved. These machines cost from $125 to $250 each. In the type most generally used the apples are dumped upon padded tables at the end of the sizer. From these they are placed on an endless carrier, the extra fancy apples on one side and the fancy on the other side of a partition. Choice, or C grade apples, as well as cookers and culls, are not put through the machines at the same time, although they may be sized later. The sizing device permits the apples to roll down into padded bins or receptacles placed along the side of the carrier.

Most of the growers, however, sort by hand. The sorters work at tables and sort from the loose boxes into three grades, but do not size the fruit. Sorters are paid usually by the hour. When working at a sizer they will sort 82 packed boxes, or about 120 loose boxes, a day. By hand they will sort 53 packed or about 75 loose boxes. The labor cost of sorting for those who use a sizer is $0.032 per packed box, or $0.021 per loose box, while for those who sort by hand it costs $0.046 per packed box, or $0.031 per loose box. Sorting time depends very largely on the relative freedom of the fruit from insect injuries and fungus disease.

Packing.—Packers work by the box, and men and women are paid at the same rate. Many growers prefer women to men for packing fruit. They apparently become expert packers much more quickly, and do neater work than men, although usually averaging fewer boxes during the season. Packing labor in Hood River Valley generally receives 4 to 5 cents per packed box. The 4-cent rate is paid where apples are both sized and graded for the packer; that is, where a sizing machine is used. The 5-cent rate is used where the apples are graded for the packer, but not sized; that is, when the sorting is done by hand. Packing is done at benches along the side of the sizing machine. When hand sorting is done the packers usually work at tables or benches. The diagonal method of packing is commonly used. All three grades of apples are wrapped. Sometimes cookers are also wrapped. Cardboards are placed inside both on the top and the bottom of the box. Packers earn higher wages than day help. The average packer packs 77.5 boxes per 10-hour day in the case of the 54 orchards considered.

Nailing and stamping.—All boxes are nailed, and stamped with the name of the grower, the grade, the number of apples in box, the variety, the packer's number, and the cubical contents of the box, which is 2,173 cubic inches. The nailing bench or rack is arranged with a device for holding down the box cover over the bulge so that it meets the ends of the box and can be easily nailed. The nailer is usually an expert and nails very rapidly, but for an amateur it is slow work. In all cases the nailer also stamps the boxes; in 74 per cent of all cases he also helps to wait either on the packers or on the sorters. The average nailer will nail and stamp 232 boxes per day, and the average cost per box is about 1 cent. Some men nail and stamp by piecework; the usual price paid is 1 cent per box. In the case of nailing and waiting the cost is higher, being $0.014 per box. One or more waiters, according to the number and size of the crew used in packing, carry apples to the sorters as needed, and carry graded apples from the sorters to the packers. In many cases sorters and packers wait on themselves. Especially is this true where the orchard is small and there is not a great amount of fruit to pack. In large packing crews a trucker is often employed who trucks the nailed-up boxes from the nailers and stacks them up ready to be hauled.

Where mechanical sizers are used one extra man is often employed to look after the machine and usually acts as foreman. Sixteen of the growers, or not quite one-third, had foremen who had no other duties but supervision, and whose labor is charged entirely to the boxes put out by the packers. There was but one grower of the 54 who sorted his apples as he packed them; that is to say, the packer sorted his own apples. In Colorado and many other Northwest sections a great many packers sort their own apples.

That sorters are employed more generally in Hood River than in most other sections, and that the sorting cost is about as great as the packing cost, is due largely to the fact that Hood River apples are carefully watched for spots caused by the apple scab, a fungus prevalent in that region.

The cost of all labor employed about the packing house for Hood River Valley is $0.1073 per packed box. There is a chance to lower labor costs in the packing house materially in the case of many growers. If the crew is not large the foreman may very well be a packer, sorter, nailer, or the like, but all crews, whatever their size, do need a packing foreman to see that the apples are properly sorted and packed. Some growers have already lowered their harvesting cost per box materially by increasing efficiency in the handling of harvesting crews, both inside and outside of the packing house; but in general there is room for considerable improvement in this regard.

Culls.—Under "culls" are included all apples which do not meet the standards required for box apples. The best of them are sold for "cookers" in loose boxes or crates. The poorer grades are used for making cider or they may be fed to the hogs. A cooperative cider factory is operated in Hood River, the stockholders buying stock amounting to $10 per acre for their bearing orchard land. The grower then gets the privilege of selling all his cider apples to the factory. Nonmembers receive the same price per ton as do members, but are able to dispose of their fruit only when the demand exceeds the supply offered by the members. In 1914 the price per ton for cider apples was $6, but in prior years the price of cider apples had usually been $8. Some cider apples are sold to Portland firms. Windfalls and other inferior apples are taken to the cider mill. Part of these are picked up on the ground and sacked in the orchard, and part of them come from the packing shed, where they have been handled by the sorters. Many orchardists do not pick up the fruit which drops from the trees, but leave it on the ground and allow the hogs to have it.

The term "cookers" is usually applied to those apples which have some minor defect or blemish. They are "jumble" packed and usually shipped to Portland. They average about 50 cents per box f. o. b. Hood River. Some growers do not ship "cookers." In this study "cookers" were taken into account only when marketed.

The average annual credit derived from culls, including "cookers," on the 54 farms studied is $5.13 per acre, or a net credit of $4.06 above the labor of picking and hauling, which amounted to $1.07 per acre. This, it should be remembered, is only labor in excess of that already included under harvesting and packing-house labor. Where the apples are picked up in the orchard one man will sack or pick up about 50 sacks per day. A man and team will haul about 2 tons of cider apples per load and 2 loads per day from the lower valley to Hood River, a distance usually of from 4 to 6 miles. The filled sacks weigh about 70 pounds each. In marketing the cull fruit which comes from the packing shed all the extra handling necessary is the hauling. Hence there is greater profit in handling these than in handling windfalls.

TOTAL HANDLING COSTS.

The total of all harvesting-labor cost for the 54 farms, allowing no credit for culls, is $49.14 per acre, or $0.221 per box. Deducting the net value of the culls there is a net labor cost of $45.08 per acre, or $0.203 per box. This is 53.01 per cent of all labor costs and 19.86 per cent of the total cost of production. If the labor cost of handling is added to the material and fixed cost connected with handling, which includes made-up boxes, paper, nails, and the annual packing-house costs, there is a total cost for handling of $79.92 per acre, or $0.36 per box. This is 35.21 per cent of the total annual cost of production.

TOTAL LABOR COSTS.

Table XIX summarizes the labor costs per acre and per box for both the clean-culture and the mulch-crop system of management.

TABLE XIX.—*Summary of all labor costs.*

	Clean cultural; 30 records; yield 218 boxes.				Mulch crop; 24 records; yield 228 boxes.				All records; 54 records; yield 222 boxes.			
	Cost per acre.	Cost per box.	Per cent of total labor cost.	Per cent of total cost of production.	Cost per acre.	Cost per box.	Per cent of total labor cost.	Per cent of total cost of production.	Cost per acre.	Cost per box.	Per cent of total labor cost.	Per cent of total cost of production.
Manuring	$1.60	$0.0073	1.82	0.72	$1.01	$0.0044	1.24	0.44	$1.34	$0.0060	1.58	0.59
Pruning	5.28	.0242	6.02	2.37	5.74	.0252	7.03	2.47	5.48	.0247	6.44	2.41
Disposal of brush	2.45	.0112	2.79	1.10	2.25	.0099	2.75	.97	2.36	.0106	2.77	1.04
Plowing	1.10	.0050	1.25	.49	.70	.0031	.86	.30	.92	.0041	1.08	.40
Cultivating	10.64	.0488	12.12	4.78	3.74	.0164	4.58	1.61	7.57	.0341	8.90	3.34
Irrigating	.71	.0033	.81	.32	6.66	.0292	8.15	2.87	3.35	.0151	3.94	1.48
Thinning	5.60	.0257	6.38	2.51	5.47	.0240	6.70	2.36	5.54	.0250	6.51	2.44
Propping	5.71	.0262	6.51	2.56	5.58	.0245	6.83	2.40	5.65	.0255	6.64	2.49
Miscellaneous	2.03	.0093	2.31	.91	1.17	.0051	1.43	.50	1.65	.0074	1.94	.73
Lime-sulphur spray	1.30	.0060	1.48	.58	1.52	.0067	1.86	.65	1.40	.0063	1.65	.62
Other sprays	7.21	.0331	8.21	3.24	7.70	.0338	9.43	3.31	7.43	.0335	8.74	3.27
Sowing mulch crop	......	......	......	......	.05	.0002	.06	.02	.02	.0001	.02	.01
Harvesting mulch crop	......	......	......	......	3.41	.0150	4.17	1.47	1.52	.0068	1.79	.67
Total labor cost previous to harvesting	43.63	.2001	49.70	19.58	45.00	.1975	55.09	19.37	44.23	.1992	52.00	19.49
Hay credit	......	......	......	......	9.59	.0421	11.74	4.13	4.26	.0191	5.01	1.88
Total net labor cost previous to harvesting	43.63	.2001	49.70	19.58	35.41	.1554	43.35	15.24	39.97	.1801	46.99	17.61
Haul shooks	.84	.0039	.96	.38	.82	.0036	1.00	.35	.83	.0037	.98	.37
Haul loose boxes to and from orchard	3.55	.0163	4.05	1.59	3.64	.0160	4.46	1.57	3.59	.0162	4.22	1.58
Picking	11.97	.0594	13.64	5.37	13.46	.0590	16.48	5.79	12.63	.0569	14.85	5.56
All packing house labor	23.59	.1082	26.87	10.58	24.09	.1057	29.49	10.37	23.81	.1073	27.99	10.49
Haul to station	8.40	.0385	9.57	3.77	8.14	.0357	9.97	3.50	8.28	.0373	9.74	3.65
Pick up and haul culls	1.11	.0051	1.26	.50	1.03	.0045	1.26	.44	1.07	.0048	1.26	.47
Total labor cost for harvesting	49.46	.2269	56.35	22.19	51.18	.2244	62.66	22.02	50.21	.2262	59.04	22.12
Credit for culls	5.31	.0244	6.05	2.38	4.91	.0215	6.01	2.11	5.13	.0231	6.03	2.26
Total net labor cost for harvesting	44.15	.2025	50.30	19.81	46.27	.2029	56.65	19.91	45.08	.2031	53.01	19.86
Total net cost for all labor	87.78	.4026	100.00	39.39	81.68	.3583	100.00	35.15	85.05	.3832	100.00	37.47

It will be seen from this table that soil management is the only factor of either system that has any great influence on the labor-cost items. The only credits are for hay and culls, the hay credit lowering the net cost of maintenance somewhat, this cost being $43.63 per acre in the clean-culture and $35.41 per acre in the mulch-crop orchards.

The cull credit is about the same in both cases. There is then a total net labor cost for the clean-culture orchards of $87.78 per acre, or $0.40 per box, while for those in mulch crop it is $81.68 per acre, or $0.358 per box. For all records there is a net labor cost of $85.05 per acre and $0.383 per box, while the labor cost is 37.47 per cent of the total cost of production. The net cost of maintenance for all records is $39.97, and $45.08 is the net cost for handling.

Yield per acre is the factor which has the greatest influence on the labor cost per box on the farms studied in the various regions. The higher the yield the higher the labor cost per acre but the lower the labor cost per box. It also appears that the cost of maintenance is a lower percentage of the total labor cost on those farms where the average yield is high than where it is low.

COSTS OTHER THAN LABOR.

Costs other than labor include two kinds of costs, material and fixed. Material costs include such items as manure, spray materials, seed, boxes. nails, paper, etc., while fixed costs refer to overhead charges, which are little influenced by the size of the crop. Fixed costs include equipment charge, apple-building charge, taxes, water rent, insurance, and interest on investment.

The average price per ton of manure is $1.50, and the average amount applied annually per acre is 1.48 tons, making a yearly cost of $2.22 per acre, or $0.01 per box for manure. Spray materials are charged at the regular price paid by most growers, which is $6.50 per barrel for lime-sulphur, $0.07 per pound for arsenate of lead paste, $0.01 per pound for lime, and $0.075 per pound for copper sulphate or "bluestone." Dry lead arsenate costs $0.175 per pound.

Alfalfa seed is charged at the rate of $0.18 per pound and clover at $0.20 per pound. As they are sown only occasionally, there is a very small annual charge for this item.

Shooks cost $0.095 per box, or $0.103 for the boxes made up, the contract cost for making being usually $0.80 per hundred. Paper and nails cost $0.039 per box. There is thus a total cost for boxes, including paper and nails, of $0.142 per finished box.

On the farms studied the total material costs amount to $42.80 per acre, or $0.192 per box. This is 18.86 per cent of the total annual cost of production.

In the fixed charges, which make up 43.67 per cent of the total annual cost of production, certain items are considered which many growers do not take into account, the principal charge being interest on investment. This, however, is a proper charge, as it is a factor which ofter determines the success or failure of a great many fruit growers. It is an actual cash expense to the grower who has a mortgage on his place.

The equipment charge for these farms is $6.50 per acre annually. It is made up of depreciation, upkeep, interest, and taxes on equipment. Only the spray rig is charged entirely to the orchard, charges for all other machinery being apportioned according to the relative extent to which it is used for work on the bearing orchard and on other crops. A 25 per cent annual charge is used for equipment other than the spray rig, consisting of 11 per cent depreciation, 8 per cent interest, 5 per cent upkeep, and 1 per cent taxes. The spray rig cost also amounts to about 25 per cent, but is made up somewhat differently. The total annual equipment or machinery cost is $6.50 per acre, or $0.029 per box. This is practically $0.03 per box.

The building charge is the annual charge for apple buildings, such as packing sheds or tents. This amounts to $3.27 per acre, or $0.014 per box. Many growers have very inexpensive packing sheds, but there are a few who have a very large investment in such buildings. In such instances the cost is very high. Only average conditions are considered here, and expensive packing sheds are not the rule.

Taxes are high in Hood River Valley, as in many other Northwest sections. The average annual tax per acre in the case of the 54 apple orchards is $8.19, or $0.036 per box. The orchard's share of fire insurance is $0.33 per acre, or $0.0015 per box.

Water rent amounts to $2.62 per acre for those who irrigate. This amounts to $1.56 for all records, or $0.007 per box.

Interest on investment in apple orchard, the largest item entering into the cost of production, makes up 55.85 per cent of the material and fixed costs and 34.9 per cent of the total annual cost of production on the farms studied. This cost is figured on an average investment of $990.74 per acre at 8 per cent and an average yield of 222 boxes per acre. The interest charge per acre is $79.26 and the charge per box is $0.357. This interest cost has been fully discussed under investment.

TABLE XX.—*Material and fixed costs (54 farms).*

Item.	Clean-culture; 30 records; yield, 218 boxes.			Mulch-crop; 24 records; yield, 228 boxes.			All records; 54 records; yield, 222 boxes.			
	Cost per acre.	Cost per box.	Per cent of total cost.	Cost per acre.	Cost per box.	Per cent of total cost.	Cost per acre.	Cost per box.	Per cent of material and fixed costs.	Per cent of total cost.
Manure	$1.94	$0.0089	0.87	$2.57	$0.0113	1.11	$2.22	$0.0100	1.56	0.98
Lime-sulphur	3.17	.0145	1.42	4.11	.0180	1.77	3.58	.0161	2.52	1.58
Lead	2.33	.0107	1.05	2.61	.0114	1.12	2.45	.0110	1.73	1.08
Other spray material	2.68	.0123	1.20	2.64	.0116	1.14	2.66	.0120	1.87	1.17
Seed				.71	.0031	.31	.32	.0014	.23	.14
Cost of made up boxes	22.45	.1030	10.07	23.48	.1030	10.11	22.87	.1030	16.12	10.08
Paper and nails	8.55	.0392	3.84	8.94	.0392	3.84	8.70	.0392	6.13	3.83
Total material cost	41.12	.1886	18.45	45.06	.1976	19.40	42.80	.1927	30.16	18.86
Equipment charge	6.34	.0291	2.85	6.71	.0294	2.89	6.50	.0292	4.58	2.86
Apple building charge	4.13	.0189	1.85	2.18	.0096	.94	3.27	.0147	2.31	1.44
Taxes	7.85	.0360	3.52	8.61	.0378	3.71	8.19	.0364	5.77	3.61
Insurance	.37	.0017	.17	.29	.0013	.12	.33	.0015	.23	.15
Water rent	.71	.0033	.32	2.62	.0115	1.13	1.56	.0070	1.10	.69
Interest on investment	74.53	.3419	33.45	85.17	.3736	36.66	79.26	.3570	55.85	34.92
Total fixed cost	93.93	.4309	42.16	105.58	.4632	45.45	99.11	.4458	69.84	43.67
Total material and fixed costs	135.05	.6195	60.61	150.64	.6608	64.85	141.91	.6385	100.00	62.53

Table XX gives a summary of material and fixed costs for both clean-culture and mulch-crop orchards. The two kinds of orchards have very nearly the same cost per box for material, namely, $0.188 for the clean-culture and $0.197 for the mulch-crop orchards. The difference come in the fixed costs, which are $0.43 per box for the clean-culture and $0.463 for the mulch-crop orchards. This difference is due mainly to the high valuation of land in mulch crop and the larger irrigation, or water tax, charge. The total material and fixed cost for all records amounts to $141.91 per acre, or $0.638 per box, or 62.53 per cent of the total annual cost of production. Of this total material and fixed cost, 30.16 per cent is for material and 69.04 per cent is for fixed cost, or the material cost is 18.86 per cent and the fixed cost 43.67 per cent of the total annual cost of production.

TOTAL COSTS.

The total of all annual costs, after crediting the orchard with hay and culls, is $226.96 per acre, or $1.021 per box, of which 37½ per cent is for labor and 62½ per cent is for material and fixed cost. If the orchards studied are separated into clean-culture and mulch-crop systems there is found to be a total cost of $222.83 per acre, or $1.022 per box, for the former and $232.32 per acre, or $1.019 per box, for the latter. Thus, although there is a difference in acre cost of $9.49, the difference in box cost is only $0.003, the yield per acre being 10 boxes more in the case of the orchards in mulch crops than in those under the clean-culture system.

TABLE XXI.—*Summary of all costs for Hood River (54 farms).*

	Clean-culture. 30 records; yield, 218 boxes.			Mulch-crop. 24 records; yield, 228 boxes.			All records. 54 records; yield, 222 boxes.		
	Cost per acre.	Cost per box.	Per cent of total cost.	Cost per acre.	Cost per box.	Per cent of total cost.	Cost per acre.	Cost per box.	Per cent of total cost.
Net cost of labor prior to harvest	$43.63	$0.2001	19.58	$35.41	$0.1554	15.24	$39.97	$0.1801	17.61
Net cost of labor for harvesting	44.15	.2025	19.81	46.27	.2029	19.91	45.08	.2031	19.86
Net cost of all labor	87.78	.4026	39.39	81.68	.3583	35.15	85.05	.3832	37.47
Material cost	41.12	.1886	18.45	45.06	.1976	19.40	42.80	.1927	18.86
Fixed cost	93.93	.4309	42.16	105.58	.4632	45.45	99.11	.4458	43.67
Material and fixed costs	135.05	.6195	60.61	150.64	.6608	64.85	141.91	.6385	62.53
Total cost	222.83	1.0221	100	232.32	1.0191	100	226.96	1.0217	100

Table XXI shows the summary of these costs and their relative percentage of the total annual cost.

On the farms studied the total annual cost of production is influenced by several factors, but the factor of greatest influence apparently is the average yield per acre. Table XXII has been prepared to show this influence. It will be seen that the larger the yield the higher the acre cost but the lower the box cost. For instance, in the case of orchards with a yield of 440 boxes there is a cost of $304.66 per acre, or $0.691 per box, while in the case of the other extreme, with a yield of 115 boxes per acre, there is a cost of $180.51 per acre, or $1.57 per box. In other words, the lowest yielding orchards have a total acre cost of $124.15 less than the highest yielding ones, but a total box cost of $0.88 more. Those orchards with a yield of 177 boxes per acre have an acre cost of $200.68, or $1.13 per box, as compared with orchards with a yield of 335 boxes and an acre cost of $282.27 or a box cost of $0.8421. As between these two groups the acre cost is $81.59 less in the case of the small yield, but $0.288 more per box.

TABLE XXIII.—*Relation of yield to total annual cost of production (54 farms).*

Yield (in boxes).	Average yield (in boxes).	Costs.										Number of records.
		Maintenance.		Handling.		Material.		Fixed.		Total.		
		Acre.	Box.	Acre.	Box.	Acre.	Box.	Acre.	Box.	Acre.	Box.	
150 and under	115	$36.33	$0.3168	$23.62	$0.2054	$24.64	$0.2143	$95.92	$0.8341	$180.51	$1.5706	11
151 to 200	177.6	34.63	.1950	35.37	.1992	34.23	.1927	96.45	.5431	200.68	1.1300	10
201 to 250	219.6	37.01	.1685	40.73	.1855	43.81	.1995	105.08	.4785	226.63	1.0320	17
251 to 300	270	45.05	.1669	59.80	.2215	51.97	.1925	101.12	.3745	257.94	.9554	7
301 to 400	335.2	53.88	.1607	74.37	.2219	60.36	.1801	93.66	.2794	282.27	.8421	6
Over 400	440.8	48.26	.1095	88.08	.1998	76.32	.1731	92	.2087	304.66	.6911	3
All records	222	39.97	.1801	45.08	.2031	42.80	.1927	99.11	.4458	226.96	1.0217	54

The handling and material costs per acre are the costs most affected by yield, but the box cost is little affected by these items. The maintenance cost is also affected by the yield. Yield is no doubt influenced in turn by the maintenance cost. The fixed cost per acre, however, remains practically the same for all yields. On this account the fixed cost per box on low yields is very much higher than where the yield is large. Thus with an increased yield the material and handling cost per box is not much reduced, but the fixed cost per box is very materially reduced, and to a lesser extent the maintenance cost. It is thus obvious that the higher the yield the less the cost per box, and that this reduced cost per box comes principally from decrease in the fixed charge per box.

The relation of size of orchard to annual cost of production is shown in Table XXIII. The slight increase in cost per box as the size of the orchard increases is due principally to decreased yield, for the yield per acre decreases as the size of orchard increases.

TABLE XXIII.—*Relation of size of orchards to total cost (54 farms)*

	Cost of production in orchards of each specified size.							
	5 acres and under (280-box yield, 4 records).		6 to 10 acres (228-box yield, 25 records).		11 to 20 acres (211-box yield, 19 records).		Over 20 acres (196-box yield, 6 records).	
	Per acre.	Per box.	Per acre.	Per box.	Per acre.	Per box.	Per acre.	Per box.
Maintenance	$63.26	$0.2252	$40.38	$0.1773	$35.77	$0.1695	$36.13	$0.1839
Handling	56.14	.1999	47.03	.2066	42.89	.2033	36.67	.1866
Labor cost	119.40	.4251	87.41	.3839	78.66	.3728	72.80	.3705
Material cost	53.94	.1920	43.60	.1915	41.15	.1950	37.68	.1918
Fixed cost	102.36	.3644	98.27	.4316	100.92	.4783	94.68	.4818
Material and fixed cost	156.30	.5564	141.87	.6231	142.07	.6733	132.36	.6736
Total cost	275.70	.9815	229.28	1.0070	220.73	1.0461	205.16	1.0441

From the results on the orchards studied it is evident that with a yield per acre as large as is the rule with the smaller orchards the larger orchards would show a marked decrease in the cost of production. In other words, with the yields the same in all cases the larger the acreage the less the cost per box. But as conditions exist in Hood River Valley, with the low yields on the larger acreages, the cost is not greatly affected by the size of orchard.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 519

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER January 24, 1917

POLES PURCHASED, 1915.

By Arthur M. McCreight.

INTRODUCTION.

The Forest Service, through its Office of Industrial Investigations, has compiled statistics on the number of poles purchased during 1915 in the United States by the telephone and telegraph companies, steam and electric railroads, and electric light, heat, and power companies. The census was taken exclusively by correspondence with approximately 17,000 purchasers, representing practically all the pole users in the country. About 12,000 concerns returned schedules in reply to either the first or the second request for data. This was 70 per cent of the total number of concerns to which inquiries were sent. Actually, however, the figures given in this bulletin represent between 90 and 95 per cent of the poles purchased, because the nonreporting companies were principally the smaller ones.

Information regarding the prices paid for the various species of poles was not requested.

Table I shows the number of poles purchased each year from 1907 to 1911 and for the year 1915, by kind of wood. Figures for 1911 and previous years were taken from reports compiled in cooperation with the Bureau of the Census. Statistics were not obtained for the years 1912 to 1914.

Table I.—*Poles purchased, by kind of wood, 1907 to 1911 and 1915.*

Kind of wood.	1915	1911	1910	1909	1908	1907
All kinds	4,077,964	3,418,020	3,870,694	3,738,740	3,249,154	3,283,268
Cedar	2,521,769	2,100,144	2,431,567	2,439,825	2,200,139	2,109,477
Chestnut	651,643	693,489	677,517	608,066	516,049	630,282
Pine	546,233	161,690	184,677	179,586	116,749	155,960
Oak	199,442	199,590	265,290	236,842	160,702	76,450
Cypress	67,644	72,995	75,459	77,677	90,579	100,368
All other	91,233	190,112	236,184	196,744	164,936	210,731

A total of 4,077,964 poles was reported as purchased during 1915, which represents an increase of 659,944, or 16 per cent, as compared with the number reported purchased in 1911. It is the largest number of poles reported in any single year.

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The annual demand for poles, which now exceeds 4,000,000, was supplied principally from three different regions of the United States: The northern white-cedar region of the Lake States, the chestnut region of the eastern portion of the country, and the western red-cedar region of the Northwest, which includes Idaho, Oregon, and Washington.

The principal properties called for in pole timbers are durability, strength, lightness, straightness, and a surface which takes climbing irons easily. All of the species of cedar reported purchased combine practically all of these properties in a high degree.

Cedar (including northern white, western red, southern white, and red) supplied 2,521,769 poles, or 61 per cent of the total number purchased. This is an increase of 421,625, or 16 per cent, as compared with the number purchased in 1911.

Next to cedar comes chestnut, which showed a decrease of 42,846 poles, while pine showed an increase of 384,543, or 70 per cent, as compared with the 1911 purchase. Most of the pine reported was that commonly known as southern yellow pine, and includes longleaf, shortleaf, and loblolly. Of these, the longleaf is the most durable. It is reported that loblolly pine gives very brief service unless it is treated with a preservative. Western yellow pine was also reported in small quantities, but, like loblolly, it requires a preservative treatment to insure reasonable length of service.

Oak poles were purchased in practically the same number as in 1911, while cypress poles showed a decrease of 5,351 poles. The use of cypress as a pole timber seems to be falling off each year. Cedar, chestnut, and pine together formed over 91 per cent of all poles reported purchased, cedar alone, as before stated, constituting over 61 per cent.

The minor species reported were redwood, spruce, tamarack, and osage orange. All of these, however, were reported in small quantities.

Table II shows the number of poles purchased in 1915, classified according to class of purchaser and kind of wood.

TABLE II.—*Poles purchased, by class of consumer and kind of wood, 1915.*

Kind of wood.	Total.	Telephone and telegraph companies.	Electric railways, light, and power companies.	Steam railroads.
All kinds	4,077,964	1,680,880	1,430,122	966,962
Northern white cedar	1,747,210	1,029,219	239,864	478,127
Chestnut	651,643	336,496	275,304	39,843
Western red cedar	567,770	105,590	422,312	39,868
Pine	546,233	69,787	388,210	88,236
White oak	177,799	34,644	13,110	130,045
Red cedar	117,545	21,386	8,424	87,735
Southern white cedar	89,244	16,661	14,686	57,897
Cypress	67,644	24,162	18,174	25,308
Red oak	21,643	6,912	13,001	1,730
All other	91,233	36,023	37,037	18,173

As indicated in the above table, the principal purchasers of poles were the telephone and telegraph companies. They reported 44 per cent of the total number purchased. The electric railways and power companies purchased about 35 per cent of the total, while the steam railroads purchased 21 per cent.

A decrease of 721,844 poles, or 30 per cent, was reported by the telegraph and telephone companies as compared with the number purchased by these companies in 1911, while the electric railways, light, and power companies reported an increase of 642,473 poles, or 44 per cent. The steam railroads reported an increase of 739,315, or 76 per cent, as compared with their purchases in 1911.

Table III shows the number of poles purchased, classified by length and by kind of wood. Poles are usually purchased in the round form, although occasionally a purchaser reported several species being sawed. However, these are of minor importance and were either redwood or western pine.

TABLE III.—*Poles purchased, classified by length and by kind of wood, 1915.*

Kind of wood.	Total.	Under 20 feet.	20 to 29 feet.	30 to 39 feet.	40 to 49 feet.	50 feet and over.
All kinds	4,077,964	1,236,694	1,531,441	980,091	256,236	73,502
Northern white cedar	1,747,210	540,565	755,311	373,874	67,358	10,102
Chestnut	651,643	23,992	255,951	295,717	63,676	12,307
Western red cedar	567,770	17,874	314,010	139,041	71,608	25,237
Pine	546,233	373,688	69,931	65,004	23,914	13,696
White oak	177,799	120,393	33,550	16,120	5,998	1,738
Red cedar	117,545	94,997	14,870	5,624	1,541	513
Southern white cedar	89,244	4,414	13,282	49,264	15,734	6,550
Cypress	67,644	13,048	22,211	26,316	4,542	1,527
Red oak	21,643	3,737	16,341	1,280	139	146
All other	91,233	43,986	35,984	7,851	1,726	1,686

Poles are generally classified commercially in 5-foot lengths and by diameters at specified points, principally at the tops and 6 feet from the butts. To condense the figures the poles shown in the above table are divided into classes differing in length by 10 feet.

Of the total number purchased 2,768,135, or 67 per cent, were under 30 feet. Poles of these lengths are most commonly used by the telephone and telegraph companies. The poles under 20 feet in length were reported chiefly by the rural telephone companies. Among the prominent woods reported under this classification were northern white cedar, pine, and white oak. The number of poles ranging from 30 to 50 feet in length aggregated about 30 per cent of the total, while those exceeding 50 feet in length represent but a small proportion.

All of the leading woods covered by the table contributed poles of all lengths, although red oak contributed but a small per cent of the larger poles. More than half of the white-oak and pine poles were under 20 feet in length.

In comparing the 1911 purchase of poles with the 1915 purchase, an increase of 832,966 poles under 20 feet in length was reported, while the number between 20 feet and 30 feet showed a decrease of 330,375. The total number of poles purchased in the other lengths did not vary greatly from the 1911 figures, slight increases in all being reported for 1915.

PRESERVATION.

One of the most important factors in determining the value of a pole is its ability to resist decay in contact with the soil. While durable woods are generally preferred as pole timbers, there is a tendency toward purchasing other species which are not as durable, but which can be rendered less liable to decay by preservative treatment.

In the treatment of poles several methods are used. Among these are the brush treatment; the open-tank treatment, in which the poles are stood on end in open tanks or vats containing the preservatives; and the pressure treatment, in which the poles are placed in cylinders into which the preservative is then run and pressure applied to force it into the poles. Much progress is being made in the butt treatment of cedar poles by the open-tank method, which is being used extensively in Idaho, Washington, and California, and in the Minneapolis and Chicago districts. A considerable proportion of the cedar poles sold receive a butt treatment.

The Forest Service did not request information relative to the number of poles treated by the various railroads and other companies reporting the purchase of poles. It has, however, obtained information from 102 treating plants operating throughout the United States. These plants reported a total of 125,639 poles treated in 1915, which is estimated to be about one-half of the actual number subjected to treatment. A large number are treated merely by applying the preservatives with a brush, and these were not reported.

It is impossible to submit a tabulated statement showing the number of poles treated by the different kinds of preservatives, owing to the lack of detailed information obtained. In treating the poles in 1915 the principal preservative reported was creosote oil, the average absorption being about 11 pounds to the cubic foot. About 85 per cent of the poles treated were yellow pine, while others reported were western red cedar and Douglas fir.

The cost of treating poles varies according to the kind of wood treated, kind and quantity of preservative used, and process employed, but experience has demonstrated that the adoption of a pole-treating policy generally proves economical and insures added life to the poles in service.

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BULLETIN No. 520

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

Washington, D. C. June 26, 1917

A SYSTEM OF ACCOUNTS FOR COTTON WAREHOUSES

By

ROY L. NEWTON, Assistant in Warehouse Investigations
and JOHN R. HUMPHREY, Investigator in
Market Business Practice

CONTENTS

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 520

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Washington, D. C. June 26, 1917

A SYSTEM OF ACCOUNTS FOR COTTON WAREHOUSES.

By Roy L. Newton, *Assistant in Warehouse Investigations*, and John R. Humphrey, *Investigator in Market Business Practice.*

CONTENTS.

INTRODUCTION.

The warehouse receives cotton for the account of another party, provides the owner with a proper place for conserving his product, and gives its receipt as evidence that the cotton has been stored. Upon the integrity and financial standing of the warehouse which issues this receipt depends the value of the receipt, and it should be the desire and aim of every warehouseman to give his receipt its utmost value.

The efficiency of a cotton warehouse depends in a very large degree upon its methods of keeping accounts and records of its transactions. The general use of a simple, concise system of accounts, comprehensive enough to fill the needs of the larger as well as of the small warehouse, would be a step toward the adoption of a standardized system of cotton-warehouse accounting.

To attempt to fill the need for a satisfactory system of accounts capable of general use, to suggest forms of warehouse receipts which

Note.—This bulletin should be of special interest to all cotton warehousemen and of general interest to their patrons and to those who are concerned in the reliability of warehouse receipts.

can be recommended for the use of cotton warehouses, and to promote the general use of uniform receipts are the aims of this bulletin. It describes a simple system of accounts for the use of cotton warehouses, which will be found comprehensive enough to meet the requirements of any organization which does only a cotton warehousing business.[1] A complete set of forms is shown and their use explained. More complex organizations, such as compresses which conduct a warehouse business or warehouses that maintain various other departments, of necessity will be compelled to enlarge upon a system of this character, but an effort has been made to have the primary ideas practicable even for such organizations. The best features of the systems already in use have been combined into this system, which has been tried out under commercial conditions.

Simplicity in any system of accounts is desirable, so that rapidity in handling may be attained without sacrificing accuracy, and the plan must be such that any data desired are quickly available. Information may be needed in regard to a certain lot of cotton or a certain outstanding receipt; about a specific bale in a remote corner of the warehouse or the exact number of bales a certain patron may have in storage. The records should be such that any one, or all, of these inquiries may be answered immediately. All of the forms used should be interlocking, so that if one fact is known full particulars may be obtained by a reference to that fact.

DESCRIPTION OF THE SYSTEM.

As this bulletin is intended to be sufficiently complete to enable a warehouseman to install the system, a detailed description of the forms comprising it is essential. The complete system includes the following twelve forms, which will be described in the order of their use:

(1) The tag; (2) the certificate of inspection; (3) A, B, C, D, or E), the warehouse receipt; (4) the consecutive tag record; (5) the individual account record; (6) the location book; (7) the outturn order; (8) the daily report; (9) the cash journal; (10) the cash disbursement ticket; (11) the cash receipt ticket; (12) the sale ticket.

THE TAG.

Various methods are in use in cotton warehouses for the identification of the bales, but by far the most successful, and the one most generally used, is that of the numbered tag, supplemented by a record of the owner's private mark. Form 1 (page 14) shows a form of tag that is recommended. In every instance the tag should be made of reasonably heavy waterproof paper or of linen. Double eyelets with

[1] Many warehousemen doing a small business find it convenient and profitable to deal in various commodities during the spring and summer, when there is little demand for storage. For this reason provision has been made for this class of business in the system of accounts described herein.

an extra reinforcement strip are desirable, and a double flexibie wire, preferably copper, for attaching the tag will give the best results. The tags should be numbered consecutively and used in numerical sequence throughout the season.

The selection of the tag to be used should be made with great care, as it is to become the principal means of identification of the cotton when the bale is in the warehouse. A tag of poor quality, improperly fastened to the bale with a single small steel wire, may be easily pulled or rubbed off the bale in handling or lost by the rusting of the wire. Numerous instances have occurred where the tag, even when securely fastened to the bale with a single small steel wire, has been twisted off by the action of the wind. Much trouble is caused by such a loss, especially if more than one bale is affected.

In order to provide against this contingency it is recommended to the warehouseman that he invariably take an accurate record of the customer's private marks that appear on the bale. This record will be of great assistance when it becomes necessary to establish the identity of the cotton.

Attention is called to the double eyelets and the extra reinforcing strip on the tag. These features make it especially desirable, for it is possible to tear the greater part of the tag away and still leave between the wires this strip which contains the number and thus serves the chief purpose of the tag.

It is advisable to have the tag made with the detachable coupon (see Form 1), especially when the warehouse furnishes a sample from the bale, as the coupon, which should be numbered to agree with the tag, may then be torn off, and placed inside the sample to identify it. Some warehousemen furnish a sample to the customer, and retain one at the warehouse. Where this is done the tag should have two coupons.

THE CERTIFICATE OF INSPECTION.

The certificate of inspection, (Form 2, page 15,) is a signed certificate from the weigher and grader, showing that he has tagged, weighed, graded, and inspected the bale or bales of cotton. On it is to be detailed the following data:

(1) The depositor's name and address; (2) the tag number; (3) the owner's marks; (4) the weight; (5) the grade; (6) the standard of classification used; (7) the length of staple; (8) the condition of the cotton; (9) the signature of the weigher and grader.

The sheets should be arranged in pads in order that a carbon copy of each certificate may be made. The lines of the forms in the "tag no." column may be numbered in advance with at least the last numeral of the tag numbers, in consecutive order. This will facilitate the filling in of the tag numbers and will secure numerical sequence. Attention is here called to the fact that the certificate is not the warehouse receipt, and should not be used as such. However, it may be given to the depositor, in addition to the receipt, as his private memorandum. Often it is not possible to weigh or grade the cotton immediately upon its arrival at the warehouse, and the owner may be unwilling to wait for his receipt until this is done. In this event the certificate may be issued subsequently, and the original attached to the receipt. The carbon copy of the certificate is to be used only as a record of the warehouse, and is for the information of the officer writing the receipt, who after noting upon it, in the place provided for that purpose, the numbers of the receipts which cover the cotton listed upon it, files it away, in numerical order.

A convenient size for the certificate is 7 by 9⅝ inches with ¼-inch ruling.

THE WAREHOUSE RECEIPT.

Many forms of receipts are in use in cotton warehouses, and no attempt is made to give forms here that would conform to the ideas of all warehousemen. The receipts shown embody all of the requirements of the United States warehouse Act, which is especially designed to increase the value of the warehouse receipt as collateral, with the exception of the statement that the receipt is issued subject to the United States warehouse Act and other special terms or conditions which might be required by the Secretary of Agriculture for the purposes of that act, which would of course be required only on receipts issued by warehouses licensed thereunder. The terms and conditions of receipts required by the Uniform Warehouse Receipts Act, which has been adopted by 32 States, Alaska, the District of Columbia, and the Philippine Islands, are substantially the same as those of the United States warehouse Act, except that the latter adds somewhat to the requirements embodied in the former.

The following data are required in the issuance of warehouse receipts, under the United States warehouse Act and must be embodied within the written or printed terms of such receipts, as set out in section 18 of the act:

(*a*) The location of the warehouse in which the agricultural products are stored.

(*b*) The date of issue of the receipt.

(*c*) The consecutive number of the receipt.

(*d*) A statement whether the agricultural products received will be delivered to the bearer, to a specified person, or to a specified person or his order.

(*e*) The rate of storage charges.

(*f*) A description of the agricultural products received, showing the quantity thereof, or, in case of agricultural products customarily put up in bales or packages, a description of such bales or packages by marks, numbers, or other means of identification, and the weight of such bales or packages.

(*g*) The grade or other class of the agricultural products received and the standard or description in accordance with which such classification has been made: *Provided*, That such grade or other class shall be stated according to the official standard of the United States applicable to such agricultural products as the same may be fixed and promulgated under authority of law.

* * * * * * *

(*h*) A statement that the receipt is issued subject to the United States warehouse Act and the rules and regulations prescribed thereunder.

(*i*) If the receipt be issued for agricultural products of which the warehouseman is owner, either solely or jointly or in common with others, the fact of such ownership.

(*j*) A statement of the amount of advances made and of liabilities incurred for which the warehouseman claims a lien: *Provided*, That if the precise amount of such advances made or of such liabilities incurred be at the time of the issue of the receipt unknown to the warehouseman or his agent who issues it, a statement of the fact that advances have been made or liabilities incurred and the purpose thereof shall be sufficient.

(*k*) Such other terms and conditions within the limitations of this act as may be required by the Secretary of Agriculture.

(*l*) The signature of the warehouseman, which may be made by his authorized agent: *Provided*, That unless otherwise required by the law of the State in which the warehouse is located, when requested by the depositor of other than fungible agricultural products, a receipt omitting compliance with subdivision (*g*) of this section may be issued if it have plainly and conspicuously embodied in its written or printed terms a provision that such receipt is not negotiable.

Compliance with all of the conditions of receipts issued under the United States warehouse Act is not obligatory unless warehousemen operate under that law.

Either a negotiable or a nonnegotiable receipt may be issued and it may be well to explain the two types. A negotiable receipt must state either that the goods received will be delivered to the bearer, or that they will be delivered to a specified person or his order. A receipt in which it is stated, either that the goods received will be delivered to the depositor only, or that they will be delivered only to a specified person named in the receipt, is not negotiable.

A nonnegotiable receipt should always bear the words "Nonnegotiable" or "Not negotiable" written or printed upon its face. Form 3D (page 21) shows a form of nonnegotiable receipt.

In the case of a lost or stolen receipt, if another is issued, the word "Duplicate" should always be marked across its face, and usually a bond is required in order to protect the warehouseman from loss in case of the reappearance of the original receipt. The practice in this and other transactions in connection with the receipt necessarily must vary in accordance with the State laws on the subject, and every warehouseman must be careful to comply with the applicable law of the State or other jurisdiction in which he operates.

There is a wide variance of opinion among warehousemen as to the relative merits of the one-bale and the multiple-bale forms of warehouse receipts. The tendency in many of the well-organized warehouses seems to be toward the use of the one-bale receipt, and in most cases this form seems to be preferable to the multiple-bale form. There are arguments both for and against this form. The fact that the one-bale type requires more work in its issuance is balanced by its desirability in the event that a person desires to sell or transfer only one or a few bales out of a lot that would otherwise be covered by a single receipt. Also the issuance of a separate receipt for each and every bale stored gives less opportunity for altering the receipt.

Form 3C (page 19) shows a form of multiple-bale receipt. There are occasions when this form is the more desirable than the one-bale type of receipt. When this multiple-bale form of receipt is used the original certificate of inspection is to be attached. Form 3E shows another form of multiple-bale receipt, in which the description of the bales is shown on the face of the receipt rather than on the attached certificate of inspection.

The wording of the receipt in regard to the guaranty of the grades, weights, and lengths of staple may be altered to fit the practices and policies of the various warehouses by which they are issued. However, the nearer the wording approximates an absolute guarantee of these qualities by the warehouse, the greater will be the value of the receipt. While it is true that warehouses in many instances attempt to disclaim responsibility for the descriptions they have given on the receipt it must be remembered that the persons to whom the receipts may be transferred should be protected in accepting these descriptions.

Many warehousemen guarantee their descriptions at least within reasonable variations, while some guarantee them to be absolutely correct. By so doing, these warehousemen furnish a receipt which is most acceptable as collateral. In some instances, a special charge is made for this guaranty, usually one-sixteenth of a cent per pound on the cotton, while in others the service is given without additional charge.

All receipts should be bound in book form, preferably 100 to the book, numbered consecutively, and arranged so as to allow the making of a carbon copy. This carbon copy should be plainly so marked, and should be used only for the purpose of record in the office. Some warehousemen require the depositor to give written acknowledgment of receipt for all original warehouse receipts issued. The form of the acknowledgment may be printed on the face of the carbon copy of the warehouse receipt. In case a large number of warehouse receipts are issued to one person, some other method of acknowledging receipt may be used, so as to avoid the inconvenience of a large number of signatures.

Form 3B (page 18) shows a form for the carbon copy of the negotiable receipt, one-bale type.

Upon the return of the warehouse receipts and the delivery of the cotton, the receipt should be plainly marked "Canceled" across its face. Canceled receipts should be safely filed away by a system that will make it easy to refer to them if necessary. Some warehousemen paste them back into their original places in the books, which makes them readily accessible. Others place them, with all papers in connection with the lot of cotton they represent, in an envelope, which is filed. Either of these methods is satisfactory, or the warehouseman may select any convenient method.

THE CONSECUTIVE TAG RECORD.

After the receipt is written, the next step in the operation of the system is the posting of the desired data in the consecutive tag record. (See Form 4, page 24.) This form is printed on sheets to be filed in a loose-leaf binder. The lines are numbered to agree with the tag numbers used by the warehouse, in consecutive order throughout. Thus it will be seen that when this book is posted from the data shown on the carbon copy of the receipt, a record of each bale is immediately available, because of the consecutive numbering of the individual bales as identified by the tag numbers. The size of the sheets should be 8 by 15 inches with $\frac{1}{4}$-inch ruling.

The following information is given in the consecutive tag record:

(1) The tag number; (2) the marks of the bale; (3) the name of depositor; (4) the date received; (5) the receipt number; (6) the location in the warehouse; (7) the date of delivery.

As the date of the delivery of the cotton out of the warehouse is always posted in the "Date-of-delivery" column, it is apparent at all times just which bales remain in storage.

THE INDIVIDUAL ACCOUNT RECORD.

It is advisable to have an account with each depositor, and this arrangement will be found to be useful in various ways as explained below. The individual account record (see Form 5, page 25) also is to be used in a loose-leaf binder. The accounts are filed alphabetically by the names of the depositors, alphabetical index sheets being used in the book, and the data for posting are obtained either from the carbon copies of the receipts or from the filed copies of the certificates of inspection. The sheets should be 8 by 15 inches in size with $\frac{1}{4}$-inch ruling and should provide for the following data:

(1) The date of receipt; (2) the receipt number; (3) the weight; (4) the grade; (5) the length of staple; (6) the tag number; (7) the date of delivery; (8) the number of months in storage; (9) the amounts of different charges; (10) totals; (11) accrued charges.

The principal advantage to be gained by the use of this form is that the record of each depositor's cotton is concentrated at one place on the books, and the number of bales on hand is readily apparent. This point will be appreciated by the warehouseman who deals with a large number of customers who are constantly requesting information in regard to small lots of cotton belonging to them. If the record is not in this form it is necessary to look over the entire tag record, with the attendant possibility of mistakes. In addition to this point, if the totals of accrued charges are brought up to date in the "Accrued charges" column, the monthly earnings of the warehouse are always in view. It is customary for the warehouse company to carry all charges until the cotton is taken from the warehouse. Nevertheless the company is earning revenue during the entire time that the cotton is in store, and monthly earnings should be ascertained. With all of the other charges stated, it is necessary only to compute the storage and insurance from the basis rate, to total the amounts, and to enter the sum in the column reserved for the month desired, which accounts for all of the recorded cotton remaining at the time on the page, in one operation.

The five forms described above comprise the essentials of a system of cotton-warehouse records, but the location book and the other forms described below will be found to be of great value when used in conjunction as auxiliary forms.

THE LOCATION BOOK.

The location book, a page of which is shown herewith (see Form 6, page 26), is designed to show the exact location of each bale in the warehouse, and its use will greatly facilitate the handling of cotton. Warehouses which are composed of several compartments will find its use especially beneficial, and it is essential in the smaller warehouses having a large number of customers.

In houses of the latter class there are frequent requests to locate cotton either for the purpose of procuring samples or for turning out of the warehouse. When the bales are placed in the compartment in no regular order, and no record is kept of their location, this service usually entails long search, with loss of valuable time, while with a properly kept location book the difficulty is entirely eliminated.

If a tag has been lost from a bale in a compartment, the book will aid in identifying the bale. A reference to the book will show what bales are in the compartment or row, and by checking and eliminating the bales found with tags it is a comparatively easy matter to determine the identity of the bale from which the tag has disappeared.

All changes in the location must be recorded, and it is advisable to have the book of such shape (a convenient size is 4 by 9½ inches) that it may be carried by the "outside" man at all times. The lines in the book are numbered consecutively throughout according to the tag numbers in use by the warehouse, and the sheets are ruled to show, besides the tag number, the exact location as to house, section, and tier, and the date of removal. An extra column is provided for any change which may be made in location

THE OUT-TURN ORDER.

The out-turn order (Form 7, page 27) is a signed order from the office to the "outside" man to turn out and deliver from the warehouse certain bales of cotton. This order is not written until the return and cancellation of the receipt and the application of the depositor or the holder of the receipt for delivery of his cotton. The tag numbers and marks of the bales to be delivered are listed upon the order, which serves as a checking list by which the "outside" man may check out the cotton.

A form of receipt, to be signed by the party receiving the cotton from the warehouse, is also provided. After checking out the cotton and obtaining the signature to the receipt, the "outside" man signs the statement that the work has been done as ordered and returns the order to the office.

The accumulated orders should be held until the close of the day in order to determine the number of bales delivered from the warehouse on that date for use in making out the daily report, after which they may be filed in date order for future reference.

A convenient size for these sheets is 6 by 8½ inches, and they should be arranged in gummed pads.

THE DAILY REPORT.

Form 8 (page 28) is a form of daily report for the use of managers of warehouses. By keeping this record properly an accurate knowledge of the conditions and activities of the warehouse will be maintained, and the manager will have at his disposal a great deal of information that will enable him to conduct the business more intelligently. He will know from day to day the amount of cotton in store, the amount of insurance that it is necessary to carry, the cost of labor, the per-bale cost of handling, the daily expenditures, and the cash receipts.

In making this report the number of bales received by the warehouse is determined by reference to the "consecutive tag record," and the "out-turn" orders of each day's business should not be filed until after the report is made, so that the number of bales turned out of the warehouse may be ascertained. If the totals are carried forward from day to day, the difference between the in and out columns should be the number of bales in the warehouse, any exceptions being provided for. The insurance report and the labor, collections and disbursements records are self-explanatory.

A convenient size for the daily report sheet is 8 by 10½ inches.

CASH JOURNAL.

The cash journal (Form 9, pages 29 and 30) is provided for the purpose of recording the charges and credits which are later to be posted to the various accounts in the ledger. This form is used as a double page, the charges being in columns to the left of "Items" column and the credits in columns to the right.

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The debit columns of this form are designated as follows:

Folio.	General ledger.	Grading.
Cash.	Accounts receivable.	Weighing.
Bank deposits.	Miscellaneous expenses.	Insurance.

In the "cash" column are recorded all the receipts of cash as they occur. The total is deposited when convenient and entered in the "bank deposits" column in the exact amount of the deposits made. At the end of the month the "bank deposits" column will furnish an itemized statement of the deposits and will give a record of the total receipts for the period. The deposits plus the cash balance from the previous month, which should be entered at the head of the "bank deposits" column, constitute the total debit to cash for the month. The most satisfactory method is to require a statement of account from the bank at the end of each month and to reconcile the cash to that statement.

When it is necessary to pay small items of expense in cash, a check should be drawn to "petty cash" in order to establish a fund out of which such payments can be made. This amount should be charged to "petty cash" account in the ledger. At the end of the month the total amount of such expenditures should be credited to "petty cash," and be charged to the proper expense accounts. At the beginning of the next month the fund can be renewed by drawing a check to "petty cash" for the amount of the previous month's expenditures.

All entries of general accounts not classified under separate headings should be carried in the "general ledger" column and should be posted to their respective accounts in the ledger from that column. Charges to customers for services or material should be entered in the "accounts receivable" column and be posted to the customers' accounts in the ledger.

Under "Miscellaneous expenses" should be entered all items not otherwise classified.

In order that the warehouse may know its position in regard to weighing, grading, and insurance, these items are carried under separate headings and the totals are posted to these accounts at the end of each month.

The credit columns are designated as follows:

Folio.	Accounts receivable.	Storage.
Check No.	Weighing.	Insurance.
Bank withdrawals.	Grading.	Miscellaneous.
General ledger.		

All checks issued should be listed by their numbers in the "check no." column and the amounts entered in the "bank withdrawals" column.

The difference between the totals of the "bank deposits" column and the "bank withdrawals" column is the available balance of cash in bank.

The "general ledger" column is used for the purpose of crediting the accounts debited through the "general ledger" debit column.

All payments on accounts receivable are entered in the "accounts receivable" column and from there posted to the credit of the proper individual accounts in the ledger.

The columns headed "weighing," "grading," "storage," and "insurance" receive credits to these accounts, the totals for the month or other period being posted to the respective accounts in the ledger.

Miscellaneous credits are entered in and posted from the "miscellaneous" column, and sales of material can be credited in the blank columns at the right under their appropriate headings. The monthly totals of these columns are then posted to their respective accounts in the ledger.

The size of this form should be 11 by 14 inches with ¼-inch ruling.

THE CASH DISBURSEMENT TICKET.

All expenditures of petty cash should be recorded on "cash disbursement" tickets (Form 10, page 31) which should be kept as petty cash vouchers.

THE CASH RECEIPT TICKET.

All receipts of money other than checks should be recorded upon a "cash receipt" ticket (Form 11, page 31). The practice of receiving scrip or coin without making a record of the transaction at the time of receipt often leads to discrepancies which are difficult to account for later.

THE SALE TICKET.

In warehouses handling supplies, all sales should be recorded on duplicate sale tickets, the originals being given to the customers and the duplicates retained for record in the books of account.

These sale tickets are similar to those used in any merchandising business and can be either printed specially or secured in stock form. Form 12 (page 31), is a form of sale ticket suitable for general use.

OPERATION OF THE SYSTEM.

In order to explain fully the operation of the system it may be well to follow the various steps as they occur in the process of warehousing a lot of cotton.

When the cotton arrives at the warehouse the weigher and grader first tags the bales with consecutively-numbered tags in the series then current. He then weighs, grades, and staples each bale, examines it for moisture or damage, and records the data upon the "certificate of inspection," making an original and one carbon copy. Both original and copy are then sent to the office, where the receipt is written from the data on the certificate. The original certificate is attached to the receipt only in case the form of receipt shown in Form 3B is used. If any of the other forms of receipt is issued the original certificate may be given to the storer. In every case the carbon copy of the certificate of inspection is filed in the consecutive order of the numbers on the tags, after there has been noted upon it the numbers of the receipts covering the cotton listed on it.

The receipt is now issued, and a full entry of the details required is posted to the "consecutive tag record" from the carbon copy of the receipt, against the corresponding tag numbers. Then the "individual account record" is posted from the carbon copy of the receipt, and given its alphabetical position in the binder. The amounts of the various fixed charges are posted in their respective columns.

In the meantime the cotton has been removed to its proper place in the warehouse and its location has been recorded in the location book. At some time during the day this book is taken to the office so that a proper entry of the location of the cotton may be made in the column provided for it in the consecutive tag record.

The operation is now completed except for the making of the daily report and the monthly determination of the amount earned on the lot of cotton while in storage.

Later, when the receipt is presented for delivery of the cotton, and it is found that the receipt is properly indorsed, and that a tender of all charges and advances has been made, the out-turn order is made out and delivered to the "outside" man. By referring to the location book the cotton is readily located. The bales are checked out and delivered according to the order, and a receipt is taken which shows to whom delivery was made. The "outside" man then signs the statement that the work has been performed as ordered, and the order is returned to the office. The date of delivery is then recorded in the columns provided for it. (See Forms 4 and 5.)

The returned receipt is conspicuously marked "Canceled" across its face and filed away. The accumulated out-turn orders are held until the close of the day, when they are used in determining the number of bales delivered from the warehouse. Proper entries are made on the tickets provided for the purpose, of the money received for storage and other charges, and of disbursements, and the necessary entries are made on the cash journal and posted to the ledger, as explained above.

ARRANGEMENT OF BALES IN THE WAREHOUSE.

The ideal arrangement from the standpoint of economy in handling, as well as insurance, is to stand the bales on end one bale deep. This arrangement necessitates a much larger floor space than is usually available; in case floor space sufficient for this arrangement is not available, stacking becomes necessary. In storing the bales, it is always advisable to arrange them so that the tag on each bale will be in sight.

If the bales are stacked, they may be arranged in "workway" formation, that is, beginning at one side a row should be placed, then a space should be left for a narrow aisle; then a double row and an aisle; another double row, and an aisle; and so on.

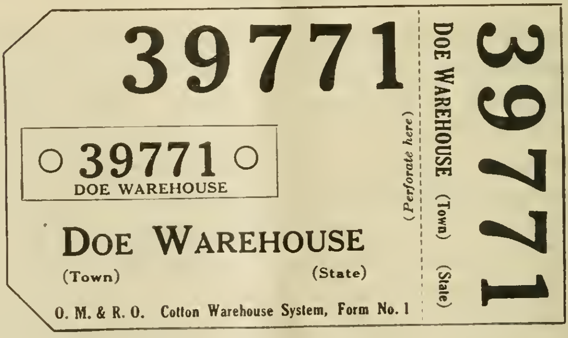
When cotton is stored on dirt floors, and even on brick or concrete floors, it is always advisable to stack the bales on wooden skids or stringers in order to raise the cotton from the floor and thus allow a circulation of air. Much damage may be avoided by this practice, especially when the cotton is placed in the warehouse while not absolutely dry or where the proper care is not taken to provide perfect drainage.

CONCLUSION.

The various operations necessary in using the Office of Markets and Rural Organization cotton warehouse accounting system have been outlined very briefly in the foregoing pages. The adoption of a uniform system of accounting for cotton warehouses should be of great benefit to warehousemen and to the public who utilize storage facilities. The system herein outlined will present to the warehouseman at all times a true and concise record of the operations of the warehouse, and the simplicity of its arrangement makes this record immediately available. The depositor has in his receipt every item of information in regard to his cotton that the warehouseman retains on his records, and this should enable the parties to avoid all misunderstandings in this respect.

The negotiable receipts shown in this system have been devised after careful study, and their requirements and conditions are designed to increase negotiability. Lack of uniformity, especially in receipts, under present conditions makes it impossible for the small warehouse of moderate means to issue a receipt that will be readily acceptable as collateral for loans outside of a limited local field. The main purpose of the United States warehouse Act enacted August 11, 1916, is to give to the warehouse receipt the greatest possible value as collateral. The form of receipt shown here embodies the principal requirements of this act and it also conforms to the essential features of the Uniform Warehouse Receipts Act, which has been adopted by 32 States, Alaska, the District of Columbia, and the Philippine Islands.

For the convenience of those interested in the system described in this bulletin and for those who desire to have the various forms printed, the Department of Agriculture, through the Office of Markets and Rural Organization, will supply, without cost, printers' copies of the several forms used in this system. Warehouses installing the system may refer to this office any questions regarding its installation or operation. When it is possible to do so, the Office of Markets and Rural Organization will render such assistance as may be required in making minor changes in the receipt or in other forms, to meet local conditions.



39771

39771
DOE WAREHOUSE

DOE WAREHOUSE
(Town) (State)

O. M. & R. O. Cotton Warehouse System, Form No. 1

(Perforate here)

DOE WAREHOUSE (Town) (State)

39771

O. M. & R. O. COTTON WAREHOUSE SYSTEM,
FORM NO. 2.

DOE WAREHOUSE.

______________ (Town) ______________ (State)

Date .... *191* ..

CERTIFICATE OF INSPECTION.

(This is not a warehouse receipt.)

INSPECTED FOR M............................OF............................

Upon inspection of each bale of the following described cotton, covered by warehouse receipts No. .... to ...., inclusive, as identified by its tag number stated below, I certify that I find it to be of the marks, weight, grade (according to the official cotton standards of the United States unless otherwise stated hereon), length of staple, and condition set opposite thereto on the same line in the next succeeding columns designated "Marks," "Weight," "Grade," "Length of Staple," and "Condition."

Tag No.	Marks.	Weight.	Grade.	Length of Staple.	Condition.	Tag No.	Marks.	Weight.	Grade.	Length of Staple.	Condition.	Tag No.	Marks.	Weight.	Grade.	Length of Staple.	Condition.
1						1						1					
2						2						2					
3						3						3					
4						4						4					
5						5						5					
6						6						6					
7						7						7					
8						8						8					
9						9						9					
0						0						0					

(Signed)________________________________
Weigher and Grader.

ORIGINAL
NEGOTIABLE

DOE WAREHOUSE.

__________ (Town.) __________ (State.)

RECEIPT No. ....
DATE..........

INCORPORATED UNDER THE LAWS OF.......... PAID IN CAPITAL STOCK $..........

WAREHOUSE RECEIPT
FOR
ONE BALE OF COTTON

RECEIVED FROM.........., of.......... on.........., 191..
the below described one bale of cotton for storage by the Doe Warehouse in its warehouse located at __________ (Town), __________ (State), subject to the conditions hereinafter set out. Said bale of cotton is identified by the tag numbers and marks, and, subject to reasonable variations and concealed defects, is of the weight, grade (according to the official cotton standards of the United States, unless expressly stated otherwise), length of staple, and condition set out below.

TAG No. .... MARKS.......... WEIGHT.......... GRADE.......... LENGTH OF STAPLE.......... CONDITION..........

Said cotton is....under shelter and....exposed to the weather, and is fully insured against loss or damage by fire unless otherwise stated on the face of this receipt.

The Doe Warehouse claims a lien on said cotton for charges, advances made, and liabilities incurred as follows: Storage from date of receipt of cotton at the rate of......per month or fractional part thereof.......... ....
Insurance from date of receipt of cotton at the rate of ...... per month or fractional part thereof.......... ....
Weighing.......... ....
Grading.......... ....
Stapling.......... ....
Freight charges.......... ....
Money advanced.......... ....
Miscellaneous.......... ....

Upon return of this receipt properly indorsed and the payment of all charges, advances, and liabilities thereon, the cotton described herein will be delivered immediately to..........or his order.

(Signed)..........

Per..........

(Title.)

OM & RO Cotton Warehouse System, Form No. 3A.

INDORSEMENTS.

STATEMENT OF LIENS.

I hereby certify that, other than the following, there are no liens or mortgages against the cotton described on the face of this receipt.

(Signed) ------------------------------------

Witness: ------------------------------------

Reverse side Form No. 3A.

COPY
NOT NEGOTIABLE

DOE WAREHOUSE.

________ (Town) ________ (State)

INCORPORATED UNDER THE LAWS OF..............................

RECEIPT NO. ....
DATE..........................
PAID IN CAPITAL STOCK $..............

WAREHOUSE RECEIPT
FOR
ONE BALE OF COTTON.

RECEIVED FROM ...., of............................, on......................................, 191..
the below described one bale of cotton for storage by the Doe Warehouse in its warehouse located at ________ (Town), ________ (State), subject to the conditions hereinafter set out. Said bale of cotton is identified by the tag number and marks, and, subject to reasonable variations and concealed defects, is of the weight, grade (according to the official cotton standards of the United States unless expressly stated otherwise), length of staple, and condition set out below.

TAG NO. .... MARKS.......... WEIGHT.......... GRADE.......... LENGTH OF STAPLE.......... CONDITION..........

THIS IS A CARBON COPY OF THE ORIGINAL RECEIPT AND IS USED AS AN OFFICE RECORD ONLY.[1]

Date.................., 191..

RECEIVED of the DOE WAREHOUSE this date the ORIGINAL NEGOTIABLE WAREHOUSE RECEIPT, of which this is a carbon copy.[1]

....
(Depositor.)

Said cotton is....under shelter and....exposed to the weather, and is fully insured against loss or damage by fire unless otherwise stated on the face of this receipt.

The Doe Warehouse claims a lien on said cotton for charges, advances made, and liabilities incurred as follows: Storage from date of receipt of cotton at the rate of......per month or fractional part thereof.............................. ....
Insurance from date of receipt of cotton at the rate of ...... per month or fractional part thereof.............................. ....
Weighing.............................. ....
Grading.............................. ....
Stapling.............................. ....
Freight charges.............................. ....
Money advanced.............................. ....
Miscellaneous.............................. ....

OM & RO Cotton Warehouse System, Form No- 3B.

Upon return of this receipt properly indorsed and the payment of all charges, advances, and liabilities thereon, the cotton described herein will be delivered immediately to..............................or his order.

(Signed)..............................

Per..............................
(Title.)

[1] In printing for actual use, this statement should be printed transversely across the face of the copy.

ORIGINAL
NEGOTIABLE

DOE WAREHOUSE

________ (Town.) ________ (State.)

RECEIPT No. ....
DATE ...., 19..

INCORPORATED UNDER THE LAWS OF .... PAID IN CAPITAL STOCK $..............

WAREHOUSE RECEIPT
FOR
......BALE.... OF COTTON

RECEIVED FROM ...., of ...., on ...., 19.. ...... bales of cotton, described in the attached certificate, for storage by the Doe Warehouse, in its warehouse located at ....(Town.), ...(State.), subject to the conditions hereinafter set out. Said ...... bales of cotton are identified by the tag numbers and marks, and, subject to reasonable variations and concealed defects, are of the weights, grades (according to the official cotton standards of the United States unless expressly stated otherwise), lengths of staple, and condition set out in the attached certificate.

Said cotton is .... under shelter and .... exposed to the weather, and is fully insured against loss or damage by fire unless otherwise stated on the face of this receipt.

The Doe Warehouse claims a lien on said cotton for charges, advances made, and liabilities incurred, as follows:

Storage from date of receipt of cotton, at the rate of ...... per month or fractional part thereof, per bale.......... ....
Insurance from date of receipt of cotton, at the rate of ...... per month or fractional part thereof, per bale.......... ....
Weighing.......... ....
Grading.......... ....
Stapling.......... ....
Freight charges.......... ....
Money advanced.......... ....
Miscellaneous.......... ....

Upon return of this receipt, properly indorsed, and the payment of all charges, advances, and liabilities thereon, the ...... bales of cotton, described in the attached certificate, will be delivered immediately to.................................... or his order.

(Signed)....................................

Per....................................
(Title.)

OM&RO Cotton warehouse system, Form No. 3C.

INDORSEMENTS.

STATEMENT OF LIENS.

I hereby certify that, other than the following, there are no liens or mortgages against the cotton described in the attached certificate.

(Signed) -----------------------------------

Witness: ---------------------------

ORIGINAL
NONNEGOTIABLE

DOE WAREHOUSE.

(Town.) (State.)

RECEIPT NO. ....
DATE ...., 191..

INCORPORATED UNDER THE LAWS OF .... PAID-IN CAPITAL STOCK $..............

WAREHOUSE RECEIPT
FOR
ONE BALE OF COTTON.

RECEIVED FROM ...., OF ...., ON ...., 191.. the below-described one bale of cotton for storage by the Doe Warehouse in its warehouse located at ....(Town.), ...(State.), subject to the conditions hereinafter set out. Said bale of cotton is identified by the tag number and marks and, subject to reasonable variations and concealed defects, is of the weight set out below:

TAG NO. .... MARKS .... WEIGHT ....

Said cotton is .... under shelter and .... exposed to the weather and is fully insured against loss or damage by fire unless otherwise stated on the face of this receipt.

The Doe Warehouse claims a lien on said cotton for charges, advances made, and liabilities incurred, as follows:

Storage from date of receipt of cotton at the rate of ...... per month or fractional part thereof...	....
Insurance from date of receipt of cotton, at the rate of ...... per month or fractional part thereof.	....
Weighing....................................	....
Freight charges..............................	....
Money advanced..............................	....
Miscellaneous................................	....

OM & RO Cotton Warehouse System, Form No. 3D.

Upon return of this receipt and the payment of all charges, advances, and liabilities thereon the cotton described herein will be delivered immediately to

....

(Signed)..

Per...
(Title.)

ORIGINAL
NEGOTIABLE

DOE WAREHOUSE

______ (Town). ______ (State).

RECEIPT NO. ------

DATE ----------------191--

INCORPORATED UNDER THE LAWS OF ------------------------ PAID IN CAPITAL STOCK $--------------

WAREHOUSE RECEIPT

FOR ...... BALE.. OF COTTON

RECEIVED FROM ------------------------OF---------------------------ON---------------------191--

Tag number.	Marks.	Weight.	Grade.	Length of staple.	Condition.	Tag number.	Marks.	Weight.	Grade.	Length of staple.	Condition.

Said cotton is .... under shelter and is .... exposed to the weather and is fully insured against loss or damage by fire unless otherwise stated on the face of this receipt.

O. M. & R. O. Cotton Warehouse System Form No. 3E.

the herein-described ...... bales of cotton for storage by the DOE WAREHOUSE in its warehouse located at ...., ... subject
(Town.) (State.)
to the conditions hereinafter set out. Said ...... bales of cotton are identified by the tag numbers and marks, and, subject to reasonable variations and concealed defects, are of the weights, grades (according to the official cotton standards of the United States unless expressly stated otherwise), lengths of staple, and condition set out herein.

The DOE WAREHOUSE claims a lien on said cotton for charges, advances made, and liabilities incurred as follows:

Storage, from date of receipt of cotton, at the rate of......
per month, or fractional part thereof per bale........ ....
Insurance, from date of receipt of cotton, at the rate of
...... per month, or fractional part thereof per bale. ....
Weighing.. ....
Grading... ....
Stapling.. ....
Freight charges....................................... ....
Money advanced.. ....
Miscellaneous... ....

Upon return of this receipt, properly indorsed, and the payment of all charges, advances, and liabilities thereon, the herein described ......bales of cotton will be delivered immediately to..............
.... or his order.

(Signed)..........................

Per..........................
(Title.)

INDORSEMENTS.

STATEMENT OF LIENS.

I hereby certify that, other than the following, there are no liens or mortgages against the cotton described on the face of this receipt.

(Signed)------------------------------

Witness---------------------------

Reverse side Form No. 3E.

O. M. & R. O. COTTON WAREHOUSE SYSTEM, FORM NO. 4.

CONSECUTIVE TAG RECORD

Tag No.	Marks.	Depositor.	Date received.	Receipt No.	Location.	Date of delivery.	Tag No.	Marks.	Depositor.	Date received.	Receipt No.	Location.	Date of delivery.
1							4						
2							5						
3							6						
4							7						
5							8						
6							9						
7							0						
8							1						
9							2						
0							3						
1							4						
2							5						
3							6						
4							7						
5							8						
6							9						
7							0						
8							1						
9							2						
0							3						
1							4						
2							5						
3							6						

O. M. & R. O. COTTON WAREHOUSE SYSTEM
FORM NO. 5

INDIVIDUAL ACCOUNT RECORD

STORED FOR ______________________ ADDRESS ______________________

Date received.	Receipt No.	Weight.	Grade.	Length of staple.	Tag No.	Date of delivery.	Months in storage.	Storage.	Insurance.	Weighing.	Grading and stapling.	Turning out.	Freight.	Advances.	Total.	Accrued charges.
																January
																February
																March
																April
																May
																June
																July
																August
																September
																October
																November
																December

O. M. & R. O. COTTON WAREHOUSE SYSTEM, FORM NO. 6.

LOCATION.

Original.				Transfer.			Out.
No.	House.	Section.	Tier.	House.	Section.	Tier.	
1							
2							
3							
4							
5							
6							
7							
8							
9							
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							
0							
1							
2							
3							
4							
5							
6							
7							

O. M. AND R. O. COTTON WAREHOUSE SYSTEM FORM NO. 7.

OUTTURN ORDER.

Date ---------------

Turn out of the warehouse and deliver to

--------------------------------- ---- --------B/C

as described by the following tag numbers and marks:

Tag No.	Marks.	✓	Tag No.	Marks.	✓	Tag No.	Marks.	✓

(Signed) ------------------------------

Work done as ordered

-------------------19--

Received for --------------from the DOE WAREHOUSE
the above checked---------B/C

(Signed)----------------------

Per----------------------

O. M. & R. O. Cotton Warehouse System.
Form No. 8.

DAILY REPORT OF OPERATION

DOE WARHOUSE, ______ (Town.) ______ (State.)

Date....................

COTTON

IN		OUT	
Received previous to date........	........b/c	Turned out previous to date.......	........b/c
Received to-day................	........b/c	Turned out to-day................	........b/c
Total....................	........b/c	Total....................	........b/c
Exceptions....................	........b/c	Number of bales on hand..........	........b/c

INSURANCE

Previously carried..................	$........	Premiums........................	$........
New policies......................	$........	Premiums........................	$........
Canceled........................	$........	Return premiums..................	$........
Total to-night..................	$........	Net........................	$........

LABOR

Paid out for labor this week / month..	$........
Number bales handled..	
Cost per bale (cents)..	$........

CASH RECEIPTS		CASH DISBURSEMENTS	
Previously reported..................	$........	Previously reported..................	$........
Received to-day....................	$........	Paid out to-day....................	$........
Total........................	$........	Total........................	$ ....

Balance...................... $..........

REMARKS

This report includes—
Cash receipts No. ..... to No. ......
Cash disbursements No. ..... to No. ......
Duplicate checks No. ..... to No. ......

....
Warehouseman.

O. M. & R. O. COTTON WAREHOUSE SYSTEM,
FORM NO. 9.

DEBIT.

CASH JOURNAL.

Insurance.	Weighing.	Grading.	Miscellaneous expenses.	Accounts receivable.	General ledger.	Bank deposits.	Cash.	Date.	Folio.	Item.

O. M. & R. O. Cotton Warehouse System,
Form No. 9.

CREDIT.

CASH JOURNAL.

Folio.	Check No.	Bank withdrawals.	General ledger.	Accounts receivable.	Weighing.	Grading.	Storage.	Insurance.	Miscellaneous.			

O. M. & R. O. COTTON WAREHOUSE SYSTEM.
FORM NO. 10.

CASH DISBURSEMENT TICKET.

No. ....

By ....

Paid to .... Date ...., 191..

	Amount.	

O. M. & R. O. COTTON WAREHOUSE SYSTEM.
FORM NO. 11.

CASH RECEIPT TICKET.

No. ....

By ....

Received from .... Date ...., 191..

	Amount.	

O. M. & R. O. COTTON WAREHOUSE SYSTEM.
FORM NO. 12.

SALE TICKET.

Date ....

Sold to ....

By ....

TOTAL SALES		

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATING TO MARKETING OF COTTON.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Studies of Primary Cotton Market Conditions in Oklahoma. (Department Bulletin 36.)

Relation of Cotton Buying to Cotton Growing. (Department Bulletin 60.)

Economic Conditions in Sea Island Cotton Industry. (Department Bulletin 146.)

Cotton Warehouses: Storage Facilities now Available in the South. (Department Bulletin 216.)

Cotton Warehouse Construction. (Department Bulletin 277.)

Disadvantages of Selling Cotton in the Seed. (Department Bulletin 375.)

Relation Between Primary Market Prices and Qualities of Cotton. (Department Bulletin 457.)

A Study of Cotton Market Conditions in North Carolina with a View to Their Improvement. (Department Bulletin 476.)

Cotton Ginning Information for Farmers. (Farmers' Bulletin 764.)

Losses from Selling Cotton in the Seed. (Farmers' Bulletin 775.)

Cotton Improvement on a Community Basis. (Separate 579 from Yearbook 1911.)

Improved Methods of Handling and Marketing Cotton. (Separate 605 from Yearbook 1912.)

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

Cotton, the Greatest of Cash Crops. (Office of the Secretary Circular 32.) Price 5 cents.

Controlling the Boll Weevil in Cotton Seed and at Ginneries. (Farmers' Bulletin 209.) Price 5 cents.

A Profitable Cotton Farm. (Farmers' Bulletin 364.) Price 5 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 521

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C. PROFESSIONAL PAPER March 30, 1917

COURSES IN SECONDARY AGRICULTURE FOR SOUTHERN SCHOOLS

(FIRST AND SECOND YEARS)

By

H. P. BARROWS, Specialist in Agricultural Education

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 521

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C. PROFESSIONAL PAPER March 30, 1917

COURSES IN SECONDARY AGRICULTURE FOR SOUTHERN SCHOOLS.[1]

(FIRST AND SECOND YEARS)

By H. P. Barrows, *Specialist in Agricultural Education, States Relations Service.*

CONTENTS.

INTRODUCTION.

The following outlines are the result of a demand for a more uniform standard in agricultural instruction in secondary schools of the South. They are to cover work in agriculture for the first two years of a 4-year course. It is assumed that the students have had work in nature study and a general course in elementary agriculture in the graded or rural school.

ADAPTATION TO LOCAL CONDITIONS.

It is not expected that all the lessons will be given in their present order of sequence. It is left with the local teacher or supervisor to work out a seasonal sequence or such order of presentation as will fit local needs. Neither is it expected that topics will be given equal importance in all districts. In adapting these courses to meet local needs it may be necessary to expand one subject or topic at the expense

[1] Prepared under the direction of C. H. Lane, Chief, Specialist in Agricultural Education.

of another. For example, lessons are outlined covering wheat, rice, and cane. It is not expected that these topics will be of equal importance in any one district. Where rice or cane is important it may not be necessary to treat wheat as a lesson, in which case more time may be given the other crops.

Adaptation to students.—The lessons should be adapted to the needs and capacities of the students. Particular care should be taken with those lessons dealing with the science underlying agricultural practice that the subject be kept within the range of secondary students. For example, students may get a comprehension of how plants grow and the principles which underlie plant breeding without going into technical plant physiology and genetics. Likewise, as an aid to a better understanding of the practice of feeding, students should know the simpler aspects of digestion and assimilation and understand the basis for scientific feeding, yet preliminary lessons on these subjects need not involve anything beyond very elementary chemistry and physiology. The extent to which these lessons are considered will depend upon the maturity of the students and their training in elementary science.

USE OF TEXTS AND REFERENCES.

It is hoped that the outlines with the references given will keep the instructor from following a textbook too closely. A list of books for use as general references is given at the end of each course. While the students may be required to buy one or more books during the course, these texts should in all cases be supplemented and adapted to both the student and the community by making special assignments to other references. Special references to bulletins of this department[1] are given with nearly every lesson. It is expected that publications of the State agricultural college, experiment station, or board of agriculture will be used also, especially the bulletins of the State in which the school is located. It is assumed that the school will maintain files of such publications of their own State as pertain to agriculture, the Yearbooks of the United States Department of Agriculture, and all Farmers' Bulletins pertaining to the agriculture of the district in which the school is located. Reference material should be secured early so that it will be available as the lessons are taken up.

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[1] Farmers' Bulletins and Yearbooks of the United States Department of Agriculture may be obtained free as long as the supply lasts, on application to the Secretary of Agriculture, Washington, D. C., or to any Senator or Representative in Congress. Other publications of the Department of Agriculture and those named when no longer available for free distribution may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at a nominal price. Price lists covering various Government publications may be obtained free from the Superintendent of Documents. Each teacher should secure a copy of Price List No. 16, which includes Farmers' Bulletins, Yearbooks, and department bulletins of the United States Department of Agriculture.

Lists of these publications prepared for teachers may be obtained from the agricultural instruction division of the States Relations Service.

USE OF ILLUSTRATIVE MATERIAL.

In connection with most of the lessons suggestions are made for illustrative material to use in the classroom. The instructor should go over the course early in the year, as much of this material must be gathered in season or secured from a distance.

DISTRIBUTION OF TIME AND CREDIT.

In the preparation of the outline it has been assumed that there will be in the school year 36 weeks of five days each. Periods of 45 to 60 minutes, three days each week, are to be spent in the classroom, and time equal to two hours a day, two days in the week, in field trips, practicums, and home-project work. One hundred and four lessons are given, leaving four classroom periods for examinations or reviews. In the course in soils and crops the remainder of the time is divided equally between the laboratory and home projects. In the course in animal husbandry relatively more time is left for home work. As many practicums may be worked out at home to greater advantage than at school, credit should be given for such work when evidence is given that it is properly done. Work involving skill in farm operations is suited especially well to home practicums. Credit for home work should be allowed on the same basis as that given for practical work at school—that is, two hours' work for one hour credit.

THE HOME PROJECT.[1]

In the course in soils and crops time equal to 36 double periods, or 72 hours, is left for the student's individual project. This approximates the time needed to produce an acre of corn, hence, growing an acre of corn may be required of the student before he is given credit for the course. It is even more necessary to adapt practicums and projects to the needs of the student and the community than it is to adapt the work of the classroom. All students in the course may not be able to grow an acre of corn, but it may be possible for them to grow some other crop. Projects should be provided for students who do not live on farms, as they are in special need of practical instruction. Where the school owns a farm it may be possible for all such students to work out their projects at the school, or if they can secure work upon a farm which may be connected in a definite way with their course, credit should be given for such work as a substitute for a home project.

[1] See U. S. Department of Agriculture Bulletin 346, Home Projects in Secondary Courses in Agriculture.

OUTLINE FOR SOILS AND CROPS—FIRST YEAR.

(One unit.)

HOW PLANTS GROW.

(Nine lessons, three double periods for practical work.)

Reference: Any modern high-school text in botany.

Lesson 1.—*Development of a Plant from the Seed.*

1. What the seed represents.
2. Conditions essential to development.
3. Vitality of seeds.
4. Parts of seed and plantlet.
5. Testing seeds.

Illustrative material: Germinating seeds of different types.

Exercise 1.—*Germination Test of Seeds.*

Purpose: Testing for viability and to determine conditions essential to germination.

Directions: Secure a quantity of wheat or any small hardy seed known to be fresh, and another lot of the same kind of seed known to be at least 10 years old. Have each student count out 50 to 100 seeds of each sample and place them in a plate between moistened Canton flannel or blotting paper. With a slip of paper to designate the sample, this seed should be covered with another plate or a piece of glass to prevent too rapid evaporation of moisture. (Paper pie plates, one within another, if kept moist, serve well without blotters or cloths.) These plates of seeds should be kept in a warm room and enough water added to keep the seeds moist but not wet. The class as a whole should take three samples of the fresh seed, one to be kept moist, but placed where it is cold; the other two to be kept in a warm place, but one lot kept covered with water to exclude air, and the other allowed to become dry. At the end of six days the tests should show results in a vigorous germination of the fresh seed kept warm and moist and a lesser degree of vigor in the old seed and those samples deprived of warmth, moisture, and air.

Record and *report:* Each student should make a record of how the tests were made and write a report bringing out answers to the following questions: What per cent of the old and the fresh seed germinated? Why did the old seed lack vigor in germination? Why did the seed covered with water fail to germinate well? What effect did the low temperature have upon the seeds? What was the effect of the lack of moisture? What conditions are essential to the germination of seeds? Under what conditions should farm and garden seeds be tested for viability? (Tables showing optimum, minimum, and maximum temperatures at which common seeds germinate and the number of years various kinds of seeds remain viable will prove helpful in connection with a study of germination.)

Special reference: Testing Farm Seeds in the Home and in the Rural School, Farmers' Bulletin 428.

LESSON 2.—*The Work of Roots.*

1. Development of roots.
2. The plant cell.
3. Root hairs.
4. Kinds of roots.
5. Function of roots.
6. Root systems.

Illustrative material: Plants showing root hairs; charts showing structure of roots.

EXERCISE 2.—*A Study of Root Hairs and Osmosis.*

Purpose: To show how plants take in mineral food.

Directions: If the germinated wheat seed is allowed to become slightly dry between the paper pie plates or the folds of the blotting paper the root hairs will develop to an abnormal length so that they may be seen readily with the naked eye.

The method by which mineral food in solution is taken into the plant through the root hairs may be shown in the following manner: Fill a thistle tube partly full of molasses and tie over the large end of the tube a piece of moistened bladder. Insert the tube in the cork of a wide-mouthed bottle and immerse it in water colored with ink. In a few hours the water should pass through the bladder and force the molasses out of the top of the tube.

Record and *report:* Drawings should be made of a plantlet, showing the root hairs, and of the apparatus illustrating osmosis. Each student should also make a written report of the demonstration in which the following questions are answered: Why do root hairs develop to a greater extent if the roots of the plantlet become slightly dry? What is the nature of the root hairs? Upon what part of the root are they found? How is the principle of osmosis applied to the taking in of plant food by the root hairs?

LESSON 3.—*The Work of Stems.*

1. Development of the stem.
2. Structure of stems.
3. How stems grow.
4. Buds.
5. Movement of sap.
6. Kinds of stems.

Illustrative material: Different kinds of stems; charts showing cellular structure of stems.

LESSON 4.—*Leaves.*

1. Forms of leaves.
2. Arrangement.
3. Structure.
4. Photosynthesis.

Illustrative material: Leaves of different forms; charts showing structure and photosynthesis.

LESSON 5.—*Flowers.*

1. Function of flowers.
2. Parts of flowers.
3. Forms of flowers.

Illustrative material: Flowers of different forms; charts showing structure.

LESSON 6.—*Fertilization of the Ovule.*

1. Conditions essential to fertilization.
2. How the pollen reaches the ovule.
3. Devices for securing cross-pollination.

Illustrative material: Charts showing fertilization of the ovule.

LESSON 7.—*Some Principles of Plant Breeding.*

1. Law of heredity.
2. Law of variation.
3. Selection.
   (*a*) Natural.
   (*b*) Selection by man.
4. Inducing variation.
5. Technique of cross-pollination.
6. Propagation.
   (*a*) Sexual.
   (*b*) Asexual.

Illustrative material: Chart showing Mendel's law.

EXERCISE 3.—*A Study of Plant Growth.*

Purpose: To show how plants develop from the seed.

Directions: Have each student fill a flat box to a depth of 5 inches with sand. On one side seeds of corn, squash, peas, and beans should be planted at a depth of 1 inch, and on the other side the same kind of seeds 4 inches deep. The planting should be done two weeks before the study is to be made, and the box placed where it may be kept warm and moist. The seeds should be studied by the students as they germinate and as the plants develop.

Record and *report:* Drawings of an entire plant of each kind should be made and the parts named. In a written report which should accompany the drawings the following questions should be answered: In what respects are the pea, bean, and squash alike? How do they differ from the corn and wheat in germination? In relation to its cotyledons, how does the pea differ from the bean in germination? How do the cotyledons of the bean differ from those of the squash in the development of the plant? How does the squash get rid of its seed case? What service do the cotyledons render the developing plant? What happens if one or both of the cotyledons are broken off? Why may corn and peas be planted deeper than beans and squashes? How do the roots of the plants differ?

LESSON 8.—*Elements of Plant Food.*

1. Sources of plants.
2. Definition of element and compound.
3. Food from the air.
4. Food from the soil and water.

LESSON 9.—*Composition of Plants.*

1. Organic *v.* inorganic matter.
2. Crude fiber.
3. Carbohydrates.
4. Proteids.
5. Fats.

Illustrative material. Chart showing composition of plants.

SOILS.

(36 lessons, 18 periods for practical work.)

References: Any of the general texts in soils. Also, United States Department of Agriculture Bulletin 355, Extension Course in Soils. Price List No. 46, United States Public Documents Relating to Soils (for sale by the Superintendent of Documents, Government Printing Office, Washington, D. C.).

LESSON 1.—*Weather and Water in Soil Making.*

1. Weathering of rocks.
2. Work of water.
3. Ice as a factor.

LESSON 2.—*Work of Plants and Animals.*

1. Lichens and mosses.
2. Stems and roots.
3. Work of animals.
4. Sources of organic matter in the soil.
5. Life in the soil.

Illustrative material: Stones upon which lichens, mosses, or other plants are growing.

LESSON 3.—*Transportation of Soils.*

1. Residual soils.
2. Gravity as a factor—colluvial soils.
3. Water as a factor—alluvial soils.
4. Ice as a factor—glacial soils.
5. Wind as a factor—loessial soils.

EXERCISE 4.—*A Field Study of Soils.*

Purpose: To determine the nature of soil and to study the various processes of formation and transportation.

Directions: In connection with a study of soil formation the entire class should be taken to a near-by railroad cut, a gully washed by water, or some excavation where the students may study the relation of the soil to the subsoil and the underlying rock and note the effects of the various agencies in the formation and modification of soils.

Record and *report:* A written report, which should be required of each student, should bring out, with any notes of special interest, answers to the following questions: Are the soils of the neighborhood visited residual or transported? What relation, if any, do you note between the nature of the prevailing types of soils and the rocks which prevail in the district? What is the difference between the soil and subsoil? What particular effects, if any, did you note of the action of water in the making of soils? What are the effects of water in the transportation of soils? What effects of lichens, mosses, and other plants were noted? Did you note any particular effects of the work of animals? To what agents do you attribute whatever crumbling of surface rocks you have seen? Why should the farmer understand the forces and agents which are making and moving soils? Can the farmer do anything to aid the formation of soils? Can he do anything to hold the soil where it is needed?

LESSON 4.—*Physical Nature of Soils.*

1. Fineness of soils.
2. Texture of soils.
3. Weight of soils.
4. Color of soils.

LESSON 5.—*Water-holding Capacity of Soils.*

1. The soil as a reservoir for water.
2. Forms of soil moisture.
3. Relation of capacity to nature of soil.
4. Relation to depth of soil.

EXERCISE 5.—*A Study of the Water-holding Capacity of Soils.*

Purpose: To test the capacity of soils of different types to take in rainfall or irrigation water.

Directions: Tie cheesecloth over the small ends of five student-lamp chimneys, which should then be mounted in a rack with the covered ends each placed in a glass tumbler. (If the lamp chimneys can not be procured, long-necked bottles, such as vinegar bottles, may be used after the bottoms have been removed in the following manner: File a groove parallel with the bottom. Lay a poker heated red hot upon the groove. As soon as a small crack is started draw the poker around the bottle and the crack will follow.) Fill the chimneys or bottles to the same height with the following kinds of soil: (1) Gravel, (2) sand, (3) loam, (4) clay, and (5) peat or leaf mold. The soil should be made firm by jarring the rack three or four times. Pour water into each of the chimneys just rapidly enough to keep the surface of the soil covered and note the exact time before it begins to drop into the tumbler below.

To show the effects of packing take two chimneys with an equal quantity of the same kind of soil, packing it firm in one chimney and leaving it loose in the other. Repeat the water-pouring process, noting the time as before.

To show which soil drains the more readily empty and replace each tumbler as soon as all free water has disappeared from the upper surface of the soil above it. After the water has ceased dripping from all the chimneys measure and compare the water in each tumbler, making a record of the order in which they cease dripping.

To determine which soil will store up the greatest quantity of moisture weigh each chimney before and after filling it with dry soil, and again after the water has ceased dripping from it. The difference between the net weight of the dry soil and that of the wet soil is the weight of the water stored. During the time that the chimneys are dripping, which may be several days, they should be covered to prevent evaporation of water from the surface of the soils.

Record and *report:* A record should be made by each student of the time and weights involved in each part of the exercise. A written report should bring out the application of this test to the capacity of different types of soils to take in and retain rainfall and irrigation waters. The effects of plowing to loosen the soil and rolling to pack it should also be brought out in their relation to the water-holding capacity of soils.

LESSON 6.—*Temperature and Ventilation of Soils.*

1. Relation to plant growth.
2. Relation to soil moisture.
3. Relation to color.

EXERCISE 6.—Factors influencing temperature of soils.

Purpose: To impress upon the minds of the students the effects of color, drainage, and slope of land upon the temperature of the soil.

Directions: Fill two boxes 12 inches square and 8 inches deep with loam soil or the type of soil which prevails near the school, making the surface smooth. Cover the surface of one with lampblack and the other with powdered chalk or lime dust. Place both boxes in the same horizontal positions in the sun. Insert thermometers about one-half inch below the surface of each and take readings every hour during the day until two or three hours after sunset.

Fill two large flowerpots with the same kind of soil after the drainage hole of one has been stopped up with paraffin. Saturate each with equal amounts of water. Insert the bulb of a thermometer an inch below the surface in each. Set in direct sunlight and take readings twice each day for two or three days.

Fill three boxes 12 inches square and 8 inches deep with loam soil and set in line in the sunlight. Leave one level, tilt one 30° to the north and the other 30° to the south. Using thermometers as before, take readings every hour during a sunny day.

Instead of using thermometers, seeds which are known to be viable may be planted in the boxes and pots and the effects of the temperatures noted upon the growth of the plants. It will be profitable also to have each student take temperatures in the field of soils of different colors, with different degrees of drainage and with different slopes, in each case securing the same type of soil and securing all conditions except the one tested as nearly equal as possible.

Record and *report:* Each student should make a record in tabulated form showing the temperature readings for the soils under the different conditions so that results may be compared and conclusions drawn. A written report should bring out answers to the following questions: What conclusions may be drawn as to the influence of color upon the temperature of soils? Are the differences recorded in sunlight as marked as when the sun is not shining? Why does dark soil warm up more quickly than light soil? What is your conclusion as to the temperature of drained and undrained soils? Is it possible to lengthen the growing season by draining wet soils? Give reasons for the difference in temperature of the boxes tilted in different directions. What factors would you consider in selecting land that will produce early crops? What does this exercise show with regard to the value of humus in the soil?

Lesson 7.—*Chemical Nature of Soils.*

1. The soil as a source of plant food.
2. Relation to rock-forming minerals.
3. Relation to water movements.

Illustrative material: Samples of common rocks and minerals.

Lesson 8.—*Organic Matter in the Soil.*

1. Relation to physical nature of soils—texture, weight, color, temperature, ventilation, and water-holding capacity.
2. Relation to chemical nature of soils—a source of plant food.
3. Humus.

Illustrative material: Samples of muck, peat, and leaf mold.

Exercise 7.—*Effects of Organic Matter upon Soils.*

Purpose: To show how organic matter increases the water-holding capacity of soils and enhances their production.

Directions: Repeat Exercise 5 with samples 2, sand, and 4, clay, after mixing with each one-third of its volume of leaf mold or well-rotted manure. Compare the weight of each sample before and after mixing. Compare the water-holding capacity of the mixtures with that of the original samples.

Fill flower pots, 4 inches or larger (tin cans will serve the purpose if holes are punched in the bottoms for drainage), with soil as follows: (1) Sand; (2) two-thirds sand; one-third leaf mold; (3) clay; (4) two-thirds clay, one-third leaf mold; (5) loam; (6) two-thirds loam, one-third leaf mold; and (7) one-third loam, one-third sand, and one-third leaf mold. Plant the same quantity of wheat, peas, or some other quick-growing plant in each pot and keep all under equal conditions in the sunlight, giving all an equal quantity of water, using sample 7 as a guide for the need of water.

Record and *report:* Have each student make a record of the results of the two tests and answer the following questions in his report: What is the effect of organic matter on the actual weight of soils? Why does organic matter increase the water-holding capacity of both sand and clay? Why do barnyard and green manures make soils easier to work? In what other ways does organic matter increase the productiveness of soils?

LESSON 9.—*Germ Life in the Soil.*

1. Nature of bacteria.
2. Relation to organic matter.
3. Relation to nitrogen.
4. Conditions essential to growth.

Illustrative material: Charts showing forms of bacteria and nitrogen cycle.

LESSON 10.—*Classification of Soils.*

1. Basis of classification.
2. Characteristics of soil ingredients.
3. Humid and arid soils.
4. Soil surveys of United States Department of Agriculture.

Illustrative material: Soil-survey maps.

Special reference: Soil surveys of Bureau of Soils, United States Department of Agriculture. (Secure survey of county or area in which school is located.)

EXERCISE 8.—*Collection of Local Soil Types.*

Purpose: To gain practice in taking soil samples and to secure material for further study.

Directions: If a soil survey has been made of the region in which the school is located, the map which accompanies the report should be used to determine the principal soil types of the district. If no survey has been made, soils should be collected which represent general types as the clay, sand, loam, and leaf mold suggested for Exercise 9. Students should be impressed with the necessity for great care in taking samples which may be sent away for analysis.

In taking samples of soil at any great depth a soil auger is necessary. Suitable augers may be purchased, or one may be made by welding a ½-inch gas pipe with a cross bar to a 1½-inch wood auger. One yard of oilcloth will make four square pieces suitable to receive the samples as they are removed from the borings.

Borings are made by holding the auger in a vertical position, bearing down upon it and turning until the point has penetrated the ground to a depth of 2 or 3 inches. In pulling the auger out a section of soil comes out in much the same condition as it existed when in place. The process of boring a few inches out at a time is repeated until the desired depth of 3 feet, 6 feet, or more is reached.

To ascertain the character of and variations in the material from the surface downward it is necessary to bore only a few inches at a time, not to exceed 6 inches in even the lighter soils, for the reason that important changes of color and other characteristics are otherwise likely to be overlooked. It is very essential that all variations in color, texture, and structure, and the occurrence of other properties within the 3-foot or 6-foot section, as the case may be, should be carefully studied. Each sample should be designated by a letter or number to correspond with one in the report.

Record and *report:* Notes should be made of the time and place of the taking of the samples as well as detailed observations, as suggested above. If the sample is taken in uncultivated land, the nature of the native vegetation should be noted. If taken in a cultivated field, whatever is known of the previous cropping should be noted and those crops named which appear in the district to be best suited to the type of soil. The lay of the land and the nature of the underlying strata should be noted wherever possible. A written report should accompany each section of samples.

NOTE.—It will be useful in connection with both class and laboratory work to have as an exhibit in the agricultural museum columns of the representative types of the soils of the school district. These columns may vary in length from 1 to 10 feet, according to the depth of the soil. Glass tubing 1 to 2 inches in diameter may be secured for this purpose. Separate jars for each foot of soil should be used in collecting and for laboratory samples. Pint fruit jars serve well for this purpose.

LESSON 11.—*Relation of Soil Type to Crops.*

1. Adaptation of crops to soil.
2. Crops suited to leading soil types.

Illustrative material: Leading soil types of district. (To be used in Lesson 12 also.)

LESSON 12.—*Management of Soil Types.*

1. Management of light soils.
2. Management of heavy soils.

EXERCISE 9.—*A Comparative Study of Soil Types.*

Purpose: To study further the effects of the chief soil ingredients upon the physical nature of soils.

Directions: Secure samples of clay soil, sandy soil, loam, and leaf mold on the same day and keep dry in bottles until used. Note the color of each. Weigh 4 ounces of each sample and spread in shallow pans until thoroughly dry, then weigh again. The difference in weight of the sample before and after drying represents the amount of moisture which can be removed in ordinary evaporation. Take 1 ounce of each of the dry samples and heat at a high temperature in an iron pan or a large iron spoon until everything that will burn has disappeared. Weigh each sample again. The difference in weight will show approximately the amount of organic matter in each. Rub each sample with the fingers and examine with a hand lens, noting the comparative fineness of grains. Make about 1 ounce of each sample plastic with water and note comparative stickiness. Mold each of these samples into a ball, put away to dry, and then note effect of drying upon its plasticity. Saturate a small canful of each sample with water, put away to dry, noting how long it takes each sample to dry and to what extent there has been shrinkage.

To determine the relative weights of the soils use a can containing about a quart, the volume of which may be determined by the students. (Square cans are made especially for the purpose.) Weigh the empty can and then weigh it filled with each sample of soil in turn after it has been settled by jarring and made level by scraping off the top with the sharp edge of a ruler. Deduct the weight of the can to ascertain the weight of the soil. Compute the volume of the can and figure the weight of a cubic foot of each sample.

Record and *report:* In making a record of these tests the following form may be used to tabulate results:

Comparison of soil types.

Kind of soil.	Color.	Amount of moisture.	Amount of organic matter.	Relative fineness of grains.	Relative plasticity.	Effect of water.	Weight of cubic foot.
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
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LESSON 13.—*Purposes of Cultivation.*

1. Preparation of seed bed.
2. Control of weeds.
3. Tillage in relation to fertility.
4. Tillage in relation to moisture.

LESSON 14.—*Conservation of Moisture.*

1. Amounts of water used by plants.
2. Losses by evaporation.
3. The soil mulch.

EXERCISE 10.—*Rise of Capillary Water in Soils.*

Purpose: To determine the height and comparative rapidity of the rise of capillary water in soils of different types.

Directions: Fasten securely in a rack four glass tubes 3 feet long and 1 inch in diameter. After tying cheesecloth over the lower ends, fill the tubes with the following kinds of soil, respectively: Clay, sand, loam, and leaf loam. The lower ends of the tubes should be immersed to a depth of 1 inch in a pan or glasses kept filled with water. Note the time the test is started and the height to which the water has risen in each tube at the end of the following periods: Ten minutes, 30 minutes, one hour, one day, three days, and six days.

Record and *report:* Each student should tabulate the results of his observation, and in a written report to accompany the table answer the following questions: In which soil does the water rise the highest? In which does it rise most rapidly? Which soil has the greatest capacity for capillary water? Upon what factors does the rise of capillary water depend? Of what practical importance is the relation of capillary water in soils to the farmer? How will it affect his management of soils of different types?

NOTE.—As a preliminary to this exercise capillarity may be demonstrated to the class by dipping a cube of sugar in water colored with ink.

EXERCISE 11.—*Use of Water by Plants.*

Purpose: To show how plants give off moisture and to give an idea of the amount of water used by plants.

Directions: Start a pea vine or some other plant which will grow vigorously in a flower pot. After the plant is growing well cover the top of the pot with a piece of cardboard somewhat larger than the top of the pot, cutting a slit in the board for the plant. Seal the slit with pitch, wax, or tallow so that no moisture can evaporate from the soil. Cover the plant with a glass jar and set in a warm, sunny place. If the jar is cooled by wrapping it for a minute or two in a cloth wrung out of cold water, moisture will condense on the inner surface of the glass.

To determine the quantity of water used, the same plant may be used if there is a space to hold water between the surface of the soil and the cardboard. Water should be applied as needed, lifting the cardboard to apply it. Weigh all water given, keeping up the test for a month or as much longer as convenient. At the end of the test dry the plant thoroughly, weigh it, and then determine the relation between the dry matter and the water needed to produce it.

Record and *report:* Each student should make a record of the water used and make a written report of results in which he should answer the following questions: Where does the water on the glass come from? How is this water given off by plants? Is all water absorbed by the roots given off by the leaves? What is the function of water in the plant? About how much water is used to make a pound of dry matter in the plant tested? How does this test agree with published reports?

EXERCISE 12.—*Effect of Mulching on Conservation of Moisture.*

Purpose: To test the efficiency of different mulches.

Directions: Six cans or pots of equal size should be filled with equal quantities of loam soil of uniform grade. Fill within 2 inches of the top and wet thoroughly with equal quantities of water. These cans should then be treated with mulching material as follows: (1) Left as a check, (2) cover with 1½ inches of soil and pack it down, (3) cover with the same amount of the same kind of soil, but keep it loose by stirring from time to time, (4) cover with 1½ inches of gravel, (5) cover with 1½ inches of fine road dust, and (6) cover with 1½ inches of chaff, sawdust, or bits of dry leaves. Keep all cans under similar conditions. Weigh morning and evening for five days.

Record and *report:* Each student should keep a record of the weights of the cans, tabulating results to show loss by days and the total loss in a comparative way. In his report he should explain why the various forms of mulching check evaporation and make application of the principles to results in field practice.

NOTE.—Preliminary to this exercise the effects of a mulch may be demonstrated by putting powdered sugar on the top of a cube dipped in colored water, as suggested in connection with Exercise 10.

LESSON 15.—*Tillage Implements.*

1. The plow and its use.
2. Harrows and cultivators and their use.
3. Rollers and planters and their use.
4. Hoes and other hand tools.

Illustrative material: Catalogues of implement dealers (or a visit to such dealers).

LESSON 16.—*Drainage.*

1. Drainage of farm land a national problem.
2. Benefits of drainage.
3. Economics of drainage.

LESSON 17.—*Drainage*—Continued.

1. Drainage systems.
2. Tile drainage.

Special reference: Tile Drainage on the Farm, Farmers' Bulletin 524.

EXERCISE 13.—*Influence of Drainage on Plant Growth.*

Purpose: To show the effect of an outlet for surplus water.

Directions: Use two plants nearly identical in size and variety in pots of the same size filled with similar soil. Stop up the hole in the bottom of one pot with wax and leave the other open with some pieces of broken flower pot or a layer of coarse gravel covering the bottom of the pot. Give the plants an abundant supply of water, the same amount to each plant. The temperatures of the soil of each pot should be taken by placing the bulb of a thermometer 2 inches below the surface and taking readings each day. After the effects of a lack of drainage are noted on one of the plants the pots should be changed, care being taken not to disturb the soil about the roots of the plants, the watering continued, and the effect noted.

Record and *report:* A record should be made of the effects of the water upon the plants and the temperature of the soil. A written report should explain the cause of the condition of the plants in answer to the following questions: Why do most plants fail to grow well in undrained soil? What has the temperature of the soil to do with the difference in growth of the two plants? What is the effect of changing conditions with regard to drainage? How may the principles and practice of this exercise be applied to field conditions?

LESSON 18.—*Erosion of Soils.*

1. Nature of erosion.
2. Problem of erosion in the South.
3. Conditions influencing erosion.
4. Wind erosion.

Illustrative material: An erosion model. (See U. S. Dept. of Agriculture, Office of Expt. Stas. Circ. 117, Working Erosion Model for Schools.)

LESSON 19.—*Prevention of Erosion.*

1. Relation to crops grown.
2. Relation to soil management.
3. Contour planting.
4. Terracing.

Special references: The Mangum Terrace in its Relation to Efficient Farm Management. U. S. Dept. of Agriculture, Bur. Pl. Indus. Circ. 94. An Effective Method of Preventing the Erosion of Hill Land. U. S. Dept. of Agriculture, Bur. Pl. Indus. Circ. "A" 78. Economic Waste from Soil Erosion. U. S. Dept. of Agriculture Yearbook, 1913.

EXERCISE 14.—*A Field Study of Erosion and Methods of Control.*

Purpose: To make students familiar with the causes of erosion and the most efficient methods of control which will apply to local conditions.

Directions: In connection with a study in the classroom of soil erosion and methods of control the class should visit a near-by field that has become gullied and bare through washing, and on the same trip, if possible, visit farms upon which erosion has been prevented by methods best suited to the section.

Record and *report:* Each student should make a written report of the trip in which he should bring out, in addition to any notes of special interest, answers to such of the following questions as may apply: Why has the washing been especially bad upon the field visited? At what season of the year is the washing the worst? What methods of prevention or control would have been best suited to this field? To what extent is erosion prevented on the farms visited by proper plowing and cultivation? What have the methods of planting to do with erosion and its prevention? What have the systems of cropping and the kind of crops to do with succession in prevention and control of erosion? What kind of terraces appear to be best suited to this section? To what extent are open ditches and tile drains used to advantage? What suggestions do you have for improvement of the methods used?

LESSON 20.—*Nitrogen as Plant Food.*

1. Nature of the element.
2. Why nitrogen is valuable.
3. Sources of nitrogen in the soil.
4. Nitrification and denitrification.
5. Relation to leguminous plants.

LESSON 21.—*Phosphorus and Potassium.*

1. As limiting factors in plant growth.
2. Nature of the elements and their compounds.
3. Amount in typical soils—availability.

LESSON 22.—*Soil Fertility.*

1. Views on what fertility is.
2. Relation to crop production.
3. Relation to water supply.
4. Relation to physical condition of soil.

LESSON 23.—*Maintaining Soil Fertility.*

1. History of American agriculture with reference to maintenance of fertility.
2. Relation of soil fertility to national prosperity.
3. Our duty toward generations to come.
4. Relation to farm management.

Special references.—The following Farmers' Bulletins: 257, Soil Fertility. 406, Soil Conservation.

LESSON 24.—*Commercial Fertilizers.*

1. Development of the fertilizer trade.
2. Nitrogenous fertilizers.

Illustrative material: Samples of fertilizing materials and commercial fertilizers. (To be used also in lessons to follow.)

LESSON 25.—*Commercial Fertilizers*—Continued.

1. Potash fertilizers.
2. Phosphate fertilizers.
3. Mixed fertilizers.

LESSON 26.—*Commercial Fertilizers*—Continued.

1. Buying fertilizers.
2. Home mixing of fertilizers.
3. Applying fertilizers.

Special references.—The following Farmers' Bulletins: 44, Commercial Fertilizers. Composition and Use; 394, Farm Practice in the Use of Commercial Fertilizers in the South Atlantic States.

EXERCISE 15.—*Examination of Commercial Fertilizers.*

Purpose: To aid students in becoming familiar with the form and value of common fertilizing materials.

Directions: Secure samples of the following fertilizing materials in glass jars to be properly labeled for future study and use in the laboratory:

Nitrogenous fertilizers: Sodium nitrate, ammonium sulphate, cottonseed meal, linseed meal, dried blood, tankage, fish scrap, guano.

Phosphatic fertilizers: Bone meal, rock phosphate, acid phosphate, basic slag.

Potassium fertilizers: Muriate of potash, potassium sulphate, wood ashes, tobacco stems.

Secure also samples of as many of the brands of commercial fertilizers as are commonly sold upon the local market. After the students have become familiar with the common fertilizing materials they should examine the commercial brands to determine, if possible, of what they consist, and to determine their value.

Record and *report:* Each student should describe each of the fertilizing materials and state its source and value. After deciding upon a certain value or unit for the available plant food contained, the market value of each fertilizer sold on the local market should be determined.

NOTE.—In connection with a study of fertilizers in classroom and laboratory a number of problems should be assigned in which the students work out the value of certain fertilizers when applied to the land.

EXERCISE 16.—*Effects of Fertilizers upon Plant Growth.*

Purpose: To demonstrate to the students the effect of commercial fertilizers on local soils.

Directions: Secure unproductive soil of the most common type in the district. (If more than one type is common, the test may be duplicated.) Supply fertilizer to five 8-inch flower pots filled with this soil, as follows: (1) Left as a check; (2) add 5 grams of a complete fertilizer containing from 2 to 3 per cent nitrogen, 8 to 12 per cent available phosphoric acid, and 2 to 5 per cent potash; (3) same as 2 without the nitrogen; (4) same as 2 without the phosphoric acid; and (5) same as 2 without the potash. The fertilizer should be mixed thoroughly with the soil in the upper half of the pot. Moisten the soil with rain water and plant six grains of wheat in each pot. Keep moist in a warm, sunny place and note development of the plants for at least one month.

Record and *report:* Each student should keep a record of the growth of the grain in the several pots and make a written report of the test in which he makes explanation of the difference in growth.

NOTE.—If the school owns land or has use of land near the school, a number of plats may be used profitably for testing fertilizers sold in the community and to demonstrate to the students the effects of fertilizers on the growth of various crops.

EXERCISE 17.—*Home Mixing of Fertilizers.*

Purpose: To apply principles relating to the application of fertilizers and to give practice in their mixing.

Directions: The value of this exercise will depend to a great extent upon the amount of material available and its application to local needs. Each student should have an opportunity to participate. If the school does not own land upon which commercial fertilizers are to be applied, it may be possible for the class to do the mixing for some patron of the school. The most popular complete fertilizer on the local market should be duplicated as far as its essential ingredients are concerned and such mixtures as are needed for the important local crops prepared. All ingredients should be weighed accurately.

Record and *report:* Each student should keep a record of the weights and percentage composition of the materials used and compute the cost in comparison with the ready-mixed fertilizers sold on the market.

NOTE.—In connection with this exercise the students should submit formulas of other mixtures which would prove economical.

LESSON 27.—*Barnyard Manure.*

1. Benefits of barnyard manure.
2. Comparative value of different manures.
3. Factors influencing the value.

LESSON 28.—*Barnyard Manure*—Continued.

1. Care and management of manure.
2. Applying manure to the land.

Special references: Barnyard Manure, Farmers' Bulletin 192; Farm Manures and Fertilizers, U. S. Dept. of Agriculture, States Relations Service Doc. 30, Ext. S. "A" 77.

EXERCISE 18.—*A Field Study of the Care and Use of Barnyard Manure.*

Purpose: To impress upon the minds of the students the results of proper care and use of barnyard manure in contrast with the results of improper use.

Directions: The class should visit a farm where manure is left in open piles to leach away. In making a visit to any farm where improper methods are to be noted, judgment and tact must be used or offense will be given. It may be necessary for the class to merely make a casual observation in passing such a farm on the way to visit a farm where favorable comments may be made. In visiting a farm where proper methods are used in caring for manure the students should observe the effect on the growing crops and upon the farm as a whole.

Record and *report:* Each student should take notes upon what he sees and make a written report. Answers to the following questions should be included in the report: What is your estimate of the value of a ton of barnyard manure in the district? In what ways may this value be lessened? What is the most practical means of conserving the liquid manure? How may leaching be prevented? What is the most efficient method of removing manure from the stable? Is it practical to remove it to the land each day throughout the year? Is a manure spreader a paying investment for the farms visited? What is the best means of caring for the manure on these farms?

LESSON 29.—*Green Manures and Cover Crops.*

1. Value as source of humus.
2. Value as protection from erosion.
3. Legumes as a source of nitrogen.

LESSON 30.—*Green Manures and Cover Crops*—Continued.

1. Legumes suitable for green manuring.
2. Cereals suitable for green manuring.
3. Management of green manures and cover crops.

Special reference: Leguminous crops for green manuring, Farmers' Bulletin 278.

LESSON 31.—*Renovation of Worn-out Soils.*

1. Why farms are abandoned.
2. Effects of one-crop system.
3. Application of previous lessons.

Special reference: Renovation of worn-out soil, Farmers' Bulletin 245.

LESSON 32.—*Acid Soils.*

1. Causes of acidity.
2. Testing for acidity.
3. Remedies.
4. Crop adaptation to acid soils.

Illustrative material: Chemicals to demonstrate acids, bases, and salts.

LESSON 33.—*Lime and Other Amendments.*

1. Benefits of liming.
2. Soils that need liming.
3. Forms of lime and their use.
4. Gypsum and other amendments.

Illustrative material: Samples of different forms of lime.
Special reference: The Liming of Soils, Farmers' Bulletin 77.

EXERCISE 19.—*Testing Soil for Acidity.*

Purpose: To give students practice in the use of the litmus test.

Directions: Samples of soil should be taken from a field known to be acid. In applying the litmus test care should be taken to avoid handling the litmus paper with sweaty hands. Clean dishes should be used in mixing the samples of soil into a paste. Use distilled water if obtainable. After the soil has been moistened and the surface made smooth, pieces of blue litmus paper should be pressed against the smooth surface with a clean knife. The degree of acidity may be determined to some extent by the time required for the paper to turn red and the degree of coloring. After soil known to be acid is tested, soils of origin unknown to the students should be tested, each student having an opportunity to apply the test. In regions where alkali soils abound, red litmus paper should be used to test such soils.

Record and *report:* Each student should make a written report of the test, including the taking of the sample. The following questions are suggestive: What are indications of an acid soil? What is the object of making a test? Why is it important to use clean utensils? Why should the degree of acidity be determined? The report should include the time taken for each test to work and a statement of the relative shades of the slips.

EXERCISE 20.—*Effects of Lime on Soil.*

Purpose: To show that lime will correct the acidity of acid soils and aid in the crumbling of clay soils.

Directions: Mix half an ounce of air-slaked lime with a pound of soil which has been found to be acid by the litmus test. Apply the test again and note results.

Treat four pans of clay soil, each pan holding 1 pound, as follows: (1) Left as a check, (2) one-half ounce air-slaked lime, (3) 1 ounce, and (4) 2 ounces. Mix the lime thoroughly with the soil, leaving no lumps. Saturate each with water and leave to dry without stirring. After drying note the cracks which have been formed on top and then study the physical condition, noting hardness and the tendency to crumble.

Record and *report:* Each student should report effect of lime on acidity, giving reasons. Drawings should be made of the tops of the samples of clay soil after they have dried, these drawings to accompany a description of the effect of the lime on the physical condition of the soil.

NOTE.—If the school has the use of land in a section where the soils need liming, field tests should be made to determine the amount needed for important crops.

LESSON 34.—*A Local Soil Survey.*

1. Value of soil surveys.
2. Instructions regarding the taking of samples.

Illustrative material: A map of the county or district showing soil types.

LESSON 35.—*Mechanical Analysis of Soils.*

1. Value of such an analysis.
2. Methods.

Illustrative material: Charts or samples showing mechanical analysis.

LESSON 36.—*Chemical and Bacteriological Analyses.*

1. Value of such analyses.
2. Methods.

Illustrative material: Charts showing analyses of representative types.

FIELD CROPS.

(Fifty-nine lessons, 15 double periods for practical work. Home projects.)

References: Any of the general texts in field crops. Price List 44, U. S. Public Documents Relating to Plant Life. (For sale by the Superintendent of Documents, Government Printing Office, Washington, D. C.)

LESSON 1.—*Introduction.*

1. Classification of field crops.
2. Statistics and relative value.
3. Selection of crops.

Special references on corn.—The following Farmers' Bulletins: 8, Corn Culture for the South; 298, Food Value of Corn and Its Products; 303, Corn-Harvesting Machinery; 313, Harvesting and Storing Corn; 400, A More Profitable Corn-Planting Method; 414, Corn Cultivation; 537, How to Grow an Acre of Corn; 553, Pop Corn for the Home; 554, Pop Corn for the Market; 617, School Lessons on Corn.

LESSON 2.—*History and Importance of Corn.*

1. Origin and history.
2. Development of corn production.
3. Present status of industry.
4. Corn products.

Illustrative material: An exhibit of corn products.

LESSON 3.—*Classification and Varieties of Corn.*

1. Botany of the corn plant.
2. Races of corn.
3. Varieties for the South.

Illustrative material: Corn plants in different stages; specimen ears of different races.

LESSON 4.—*Judging and Exhibiting Corn.*

1. The score card for corn.
2. Selecting corn for exhibits.

Illustrative material: Score cards. Perfect and imperfect ears.

EXERCISE 21.—*Care of Seed Corn.*

Purpose: To secure material for future use and to give practice in efficient methods.

Directions.[1]

EXERCISE 22.—*Corn Judging.*

Purpose: To develop skill in selection of seed corn.

Directions.[1]

LESSON 5.—*Improvement of Corn.*

1. Importance of selection.
2. Methods of corn breeding.
3. Seed testing.

Illustrative material: Specimens of ears showing stages in improvement; different types of testers.

EXERCISE 23.—*Testing Seed Corn.*

Purpose: To develop skill in testing and to ascertain the most efficient method.

Directions.[1]

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[1] Directions for these three exercises will be found in the Agricultural Education Monthly, Vol. II, No. 6, Teaching Corn Production in Secondary Schools.

LESSON 6.—*Corn Planting.*

1. Preparation of seed bed.
2. Time of planting.
3. Depth of planting.
4. Planting machines.
5. Systems of planting.

LESSON 7.—*Soils and Fertilizers for Corn.*

1. Types of soils best suited to corn.
2. Improvement of soils.
3. Corn in the rotation.
4. Fertilizers for corn.

LESSON 8.—*Cultivation of Corn.*

1. Methods of tillage.
2. Tillage implements.
3. Control of weeds and moisture.

Special reference: Farm Practice in the Cultivation of Corn, U. S. Dept. of Agriculture Bulletin 320.

LESSON 9.—*Corn Enemies and Their Control.*

1. Fungus diseases.
2. Insect pests.
3. Other enemies.

Illustrative material: Mounted specimens of insects and diseases.

LESSON 10.—*Harvesting and Marketing Corn.*

1. Harvesting methods and machinery.
2. Marketing the crop.
3. Storing corn.

LESSON 11.—*Oats.*

1. History and importance.
2. Botany of the plant.
3. Types of oats and varieties for the South.
4. Soils and fertilizers.
5. Preparation of land and planting.
6. Care and cultivation of crop.
7. Harvesting, storing, and marketing.
8. Uses.
9. Enemies.

NOTE.—The above outline may be adapted to lessons covering crops to follow.

Illustrative material: Specimens showing types and varieties of oats and all grains which follow.

Special references.—The following Farmers' Bulletins: 420, Oats: Distribution and Uses; 424, Oats: Growing the Crop; 436, Winter Oats for the South.

EXERCISE 24.—*Treating Seed Oats for Smut.*

Purpose: To give students practice.

Directions: If the school is not to plant oats upon its own land, it may be possible for the class to treat the seed of some farmer in the neighborhood. As the formalin treatment is most generally recommended, the following directions are given for this method: Spread the seed out upon a clean floor and sprinkle thoroughly with a solution of 1 pound of formalin to 40 gallons of water. The seed should be shoveled over until it is well moistened and then covered with blankets or canvas and allowed to stand for several hours. It can then be sown at once or spread out in a clean place to dry.

NOTE.—In connection with this exercise it will be profitable to have a germination test made of samples taken before and after treatment to ascertain if the formalin has any effect upon the vitality of the seed.

LESSON 12.—*Wheat.*

Special references.—

Improvements in Wheat Culture, U. S. Dept. of Agriculture Yearbook, 1896.

Winter Wheat in the Cotton Belt, Office of Secretary of Agriculture, Special Circular.

Growing Hard Spring Wheat, Farmers' Bulletin 678.

Varieties or Hard Spring Wheat, Farmers' Bulletin 680.

LESSON 13.—*Rye.*

Special reference: Rye in the Cotton Belt, Office of Secretary of Agriculture, Special Circular.

LESSON 14.—*Barley.*

Special references.—The following Farmers' Bulletins: 427, Barley Culture in the Southern States, 443, Barley: Growing the Crop; 518 Winter Barley.

LESSON 15.—*Rice.*

Special references.—The following Farmers' Bulletins: 417, Rice Culture; 673, Irrigation Practice in Rice Growing.

EXERCISE 25.—*Collection and Study of Small Grains.*

Purpose: To familiarize students with varieties of grains suited to local conditions.

Directions: The collection and study of small grains may be carried on as extensively as time permits and as the agricultural interests of the students and community demand. The school should have an exhibit of types and varieties of grains as a part of its museum and laboratory equipment. While such exhibits may be purchased, these should be used chiefly as a means of suggestions for work to be done by students and as an aid in checking upon the naming of varieties. Each student may be assigned the collection and mounting of 10 varieties of a certain kind of cereal. Directions for this work may be obtained in Farmers' Bulletin 586, Collection and Preservation of Plant Material for Use in the Study of Agriculture.

Record and *report:* Students should make use of printed outlines in writing descriptions and reporting upon quality.

NOTE.—This work may include the use of a score card in judging those grains most important in the district.

LESSONS 16 AND 17.—*The Sorghums.*

Special references.—

Sorghum for Forage in the Cotton Belt, Office of Secretary of Agriculture, Special Circular.

The Grain Sorghums, U. S. Dept. of Agriculture Yearbook, 1913.

The following Farmers' Bulletins: 246, Saccharine Sorghums for Forage; 287, Nonsaccharine Sorghums; 448, Better Grain-Sorghum Crops; 458, Best Two Sweet Sorghums for Forage; 477, Sorghum Sirup Manufacture; 552, Kafir as a Grain Crop; 686, Uses of Sorghum Grain.

EXERCISE 26.—*A Study of Types and Varieties of Sorghums.*

Purpose: To familiarize students with a class of field crops some of which may prove of great value to local agriculture.

Directions: The school should have a fairly complete collection of the types and varieties of sorghums as heads and thrashed material. The collection and mounting of varieties grown locally should be assigned to students. The collection may be completed by purchase, or by exchange with other southern schools, of material from firms which supply agricultural laboratories. The varieties of sorghum may be grouped under the following heads: (1) Saccharine, including the varieties used for sirup; (2) nonsaccharine, or grain sorghums, including kafir, milo, and other durras, and such miscellaneous varieties as the kaolings, shallu, and darso; and (3) broom corn.

The following outline may be used in the description of each variety: (1) Head; length, circumference, and shape; (2) seed; size, shape, color, hardness; and (3) glumes; hairy or smooth, color, length.

If score cards are not obtainable from the State agricultural college or State department of agriculture, the class should make up score cards for judging both head samples and grain samples. Practice in judging may follow according to the time available and in accordance with the importance of the crop.

NOTE.—If the sorghums are not adapted to the section in which the school is located, the same study may be made of some other group of forage crops which is little known and which may give promise, such as the millets.

LESSON 18.—*Sugar Cane.*

LESSON 27.—*A Study of Sirup Making.*

Purpose: To familiarize students with modern methods in making cane sirup.

Directions: The class should visit a farm or factory where the most modern methods are in vogue. The teacher should make arrangements before the visit so that the time may be spent most profitably in a study of the processes from the grinding of the cane to the canning of the sirup.

Record and *report:* Each student should make a record of items of interest and write a report of the trip in which the following questions are answered: What are the requirements of good sirup? What equipment is needed? Discuss the degrees of efficiency of roller mills in connection with a description of the grinding process. What kind of evaporator is best suited to farm use? What is the most efficient method of straining the juice? Discuss the use of a Baumé hydrometer in connection with the boiling of the sirup. What factors are to be considered in connection with a prevention of the sirup crystallizing? Discuss the use of lime in connection with removal of impurities. How is sulphur used? What are the fundamental principles which underly the canning of sirup and other food products? What factors will determine the price received for the product?

NOTE.—This exercise may be adapted to a study of the making of sorghum sirup.

LESSONS 19 AND 20.—*Tobacco.*

Special references.—The following Farmers' Bulletins: 60, Methods of Curing Tobacco; 120, The Principal Insects Affecting the Tobacco Plant; 343, The Cultivation of Tobacco in Kentucky and Tennessee; 523, Curing Tobacco; 571, Tobacco Culture.

EXERCISE 28.—*Production of Tobacco Plants.*

Purpose: To give students practice in management of a seed bed and to test depths for planting.

Directions: Each student should participate in the preparation and planning of a seed bed for tobacco and care for the plants until they are ready to set out in the field. The work may also include the setting of the plants wherever it is possible. A portion of the seed bed should be divided to test depth of planting, as follows: (1) On the surface, (2) barely covering seeds with soil, and (3) one-half inch deep. If it is not possible to have seed beds out of doors, small flats may be used in the sunny windows of the laboratory or classroom.

NOTE.—This exercise should be omitted where tobacco is not an important crop.

LESSONS 21, 22, AND 23.—*Sweet Potatoes.*

Special references.—The following Farmers' Bulletins: 324, Sweet Potatoes; 548, Storing and Marketing Sweet Potatoes.

EXERCISE 29.—*Propagation of Sweet Potatoes.*

Purpose: To give students practice in the production of plants and to furnish material for a study of the sweet-potato plant.

Directions: This exercise should provide practice to all students in each of the following operations: (1) Selection of seed, (2) making of hotbed, (3) planting and care of bed, and (4) drawing and setting of plants. Directions for all these operations may be obtained from Farmers' Bulletin 324, Sweet Potatoes.

NOTE.—The method of propagation should be adapted to the section in which the school is located.

LESSON 24.—*Potatoes.*

Special references.—The following Farmers' Bulletins: 35, Potato Culture; 91, Potato Diseases and Their Treatment; 407, The Potato as a Truck Crop; 533, Good Seed Potatoes and How to Produce Them; 544, Potato Tuber Diseases.

LESSON 25.—*Cassava and Okra.*

Special references.—The following Farmers' Bulletins: 167, Cassava; 232, Okra.

LESSON 26.—*Miscellaneous Field Crops.*

1. Rape.
2. The cabbage family.
3. Other crops which may be of local importance.

Special reference: Rape as a Forage Crop, Farmers' Bulletin 164.

LESSON 27.—*Root Crops.*

1. Stock beets of different types.
2. Turnips, carrots, and parsnips.
3. Jerusalem artichokes.
4. Miscellaneous root crops for the South.

Special references.—

Promising Root Crops for the South, U. S. Dept. of Agriculture, Bur. Pl. Indus. Bul. 164.

Sugar Beet Growing under Humid Conditions, Farmers' Bulletin 568.

Special references on cotton.—

Bulletins and circulars upon the subject obtained from State experiment stations and departments of agriculture.

Improvement of Cotton by Seed Selection, U. S. Dept. of Agriculture Yearbook, 1902.

Cotton Improvement on a Community Basis, U. S. Dept. of Agriculture Yearbook, 1911.

Improved Methods of Handling and Marketing Cotton, U. S. Dept. of Agriculture Yearbook, 1912.

Production of Cotton under Boll Weevil Conditions, U. S. Dept. of Agriculture, Bur. Pl. Indus. Circ. "A" 71.

The Cotton Plant: Its History, Botany, Chemistry, Culture, Enemies, and Uses, U. S. Dept. of Agriculture, Off. Expt. Stas. Bulletin 33.

The following Farmers' Bulletins: 36, Cotton Seed and Its Products; 285, Advantage of Planting Heavy Cotton Seed; 286, Comparative Value of Whole Cotton Seed and Cottonseed Meal in Fertilizing Cotton; 290, The Cotton Bollworm; 302, Sea Island Cotton: Its Culture, Improvement, and Diseases; 326, Building up a Run-down Cotton Plantation; 333, Cotton Wilt; 364, A Profitable Cotton Farm; 500, Control of the Boll Weevil; 501, Cotton Improvement Under Weevil Conditions; 512, The Boll-weevil Problem; 601, A New System of Cotton Culture and Its Application; 625, Cotton Wilt and Root Knot.

LESSON 28.—*The Cotton Industry in the South.*

1. History and statistics.
2. Relation of cotton to southern agriculture.
3. Present status of the industry.

LESSON 29.—*Uses of Cotton and Its Products.*

1. Cotton lint—a source of material for clothing.
2. Cotton seed—a source of food for man, beast, and soil.

Illustrative material: An exhibit of cotton and its products.

LESSON 30.—*General Characteristics and Structure of Cotton.*

1. Botany of the cotton plant.
2. Composition of different parts of the plant.
3. Classes and grades of lint.

LESSON 31.—*Types and Varieties of Cotton.*

1. Species and types.
2. Groups and varieties of American Upland.

Illustrative material: Pictures and mounted specimens showing types and varieties.

EXERCISE 30.—*A Study of Cotton Varieties.*

Purpose: To familiarize students with the varieties of cotton suited to the section.

Directions: Each student should be required to collect, classify, and describe 10 varieties of cotton, or as many of this number as are grown in the school district.

Record and *report:* Notes should be taken regarding the fields from which the specimens are taken. The written descriptions should include: (1) Name of variety and group to which it belongs, (2) size and shape of plant, (3) time of maturity, (4) size and relative number of bolls, (5) length and quality of lint, and (6) yield (record in district).

Reference: Lessons on Cotton for the Rural Common School, United States Department of Agriculture Bulletin 294.

LESSON 32.—*Improvement of Cotton.*

1. Importance of selection.
2. Qualities needing improvement.
3. Methods of cotton breeding.

EXERCISE 31.—*Judging and Selection of Cotton.*

Purpose: To train judgment of students in selecting a variety and in the selection of plants in the improvement of a variety.

Directions: Each student should have practice with a score card to the extent that time will allow. After such practice the student should select the nearest approach to his ideal from a variety common to the district which may be designated by the instructor. This practice is preliminary to selection of seed plants in the field.

Record and *report:* A written report of the field selection should include a description of an ideal plant of the variety selected and answers to the following questions: Why should an ideal or standard of the variety be kept constantly in mind? What are the principal qualities desired in the plant? What defects are to be guarded against? What qualities in this variety need improvement? Which of these qualities are antagonistic? Which qualities will it be most profitable to strive to improve at this time? How is improvement secured through selection?

NOTE.—The students should be encouraged to use the seed of the plants selected in a breeding plat at home.

LESSON 33.—*Soils and Fertilizers for Cotton.*

1. Soils best suited to cotton.
2. Improvement and renovation of soils.
3. Cotton in the rotation.
4. Fertilizers for cotton.

LESSON 34.—*Planting and Cultivation of Cotton.*

1. Methods of planting.
2. Methods of tillage.
3. Tillage implements.
4. Control of weeds and moisture.

LESSON 35.—*The Mexican Cotton Boll Weevil.*

1. Extent of injury.
2. Injury to the plant.
3. Natural history of the insect.
4. Methods of control.

Illustrative material: Mounted specimens showing life history of boll weevil.

LESSON 36.—*Other Insect Enemies and Diseases of Cotton.*

1. The cotton bollworm.
2. Insects of minor importance.
3. Diseases of the cotton plant.

Illustrative material: Mounted specimens of insects.

LESSON 37.—*Harvesting and Marketing Cotton.*

1. Picking.
2. Ginning.
3. Baling and compressing.
4. The cotton market.

LESSON 38.—*Place of Legumes in Southern Farming.*

1. Botany of the Leguminosæ.
2. A review of symbiosis.
3. Relation of legumes to stock feeding.
4. Relation of legumes to soil feeding.
5. Legumes as food for man.

Illustrative material: Specimens of representative legumes to show flowers and fruit.

Special references.—The following Farmers' Bulletins: 121, Beans, Peas, and Other Legumes as Food; 278, Leguminous Crops for Green Manuring; U. S. Dept. of Agriculture Yearbook, 1897, Leguminous Forage Crops.

LESSON 39.—*Cowpeas.*

Illustrative material: Collection of seed of different varieties of this and crops which follow.

Special references: Cowpeas, Farmers' Bulletin 318; Cowpeas in the Cotton Belt, Office of Secretary of Agriculture Special Circular.

LESSON 40.—*Soy Beans.*

Special reference: Soy Beans, Farmers' Bulletin 372.

LESSON 41.—*Field Peas and Beans.*

Special references.—The following Farmers' Bulletins: 224, Canadian Field Peas; 289, Beans.

LESSON 42.—*Peanuts.*

Special reference: The Peanut, Farmers' Bulletin 431.

LESSONS 43 AND 44.—*The Clovers.*

Bur, red, crimson, alsike, white, sweet, and any other clovers of local importance.

Illustrative material: Mounted specimens of fresh plants of all varieties of clover. Samples of seed of each variety. Same for forage plants which follow.

Special references.—The following Farmers' Bulletins: 123, Red Clover Seed; 441, Lespedeza, or Japan Clover; 455, Red Clover; 485, Sweet Clover; 550, Crimson Clover: Growing the Crop; 579, Crimson Clover: Utilization; 646, Crimson Clover: Seed Production; 693, Bur Clover; 730, Button Clover.

LESSON 45.—*Vetches.*

Special references: Hairy Vetch for the Cotton Belt, Office of Secretary of Agriculture Special Circular. The following Farmers' Bulletins: 515, Vetches; 529, Vetch Growing in the South Atlantic States.

LESSONS 46 and 47.—*Alfalfa.*

Special references.—The following Farmers' Bulletins. 339, Alfalfa; 494, Alfalfa Seed Production.

EXERCISE 32.—*Legume Inoculation.*

Purpose: To give students practice in proper methods of inoculation.

Directions: While this exercise may be conducted with seed sown in flats in the laboratory, it will have greater value if conducted in connection with the seeding of alfalfa or any of the clovers on the school farm or the farm of a neighboring patron. In a district where any legume which gives promise has not been grown extensively a demonstration may be carried out with profit upon plats treated as follows: (1) Without inoculation, (2) inoculated by the soil-transfer method, and (3) inoculated by the pure-culture method. Directions for applying these methods may be obtained from the United States Department of Agriculture, Bureau of Plant Industry Circular 63, Methods of Legume Inoculation, or from the Farmers' Bulletins which treat the growing of the specific crop. Pure cultures for demonstration purposes may be obtained from the Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Each student should participate as far as possible in the work.

NOTE.—This exercise may be preceded with profit by a comparative study of the nodules on the various kinds of legumes found in the neighborhood of the school.

LESSONS 48 AND 49.—*The Grasses.*

Bermuda, Johnson, Sudan, Rhodes, timothy, redtop, Kentucky bluegrass, orchard grass, the brome grasses, fescues, and any other grasses of local importance.

Special references.—

Notes on Grasses and Forage Plants of Southeastern States, Agrostology Bulletin 1.

Economic Grasses, Agrostology Bulletin 14.

Some New Grasses for the South, United States Department of Agriculture Yearbook, 1912.

The following Farmers' Bulletins: 361, Meadow Fescue: Its Culture and Uses; 402, Canada Bluegrass: Its Culture and Uses; 605, Sudan Grasses as a Forage Crop.

EXERCISE 33.—*Collection and Study of Grasses.*

Purpose: To familiarize students with varieties of grasses best suited to local conditions.

Directions: Each student should collect and describe two grasses of local importance in addition to the following 10 varieties: Bermuda, Johnson, Sudan, Rhodes, timothy, redtop, Kentucky bluegrass, orchard grass, smooth brome-grass, and meadow fescue. Whenever possible, a sample of seed should accompany the sample of dried grass.

Record and *report:* The following outline from A Laboratory Manual of Cereals and Forage Crops, by Livingston and Stemple, may be followed in writing the descriptions of the grasses:

Field study of perennial grasses.

(Adapted for last of May or first of June.)

Common name____________________
Scientific name____________________
Place mostly grown____________________
Thriftiness: Vigorous, medium, weak____________________
Habit of growth:
  Stooling: Very stoloniferous, medium, not____________________
  Diameter of plants (average of 10 plants)____________________
  Number of plants per square foot for full stand____________________
Roots:
  Color: White, brown, red____________________
  Depth: Deep or shallow—medium____________________

Culms:
- Number per plant (average 10 plants)______________________________
- Height—inches (average 10 plants)______________________________
- Position: Erect, decumbent at base, decumbent______________________________
- Size: Coarse, medium, slender______________________________
- Shape: Round, elliptical, lenticular______________________________
- Color: ______________________________

Foliage:
- Abundance: Abundant, medium, scanty______________________________
- Distribution: Basal foliage, abundant, culm foliage, abundant__________
- Leaf sheath: Smooth, downy, scabrous, split to node, partly split, closed______________________________

Leaf blade:
- Length—average of 5______________________________
- Width—average of 5______________________________
- Position: Erect, ascending, drooping______________________________
- Midrib: Prominent, medium, indistinct ______________________________
- Surface: Smooth, downy, rough______________________________
- Color: Shade of green______________________________

Adapted for: Pasture, hay, both, lawn, etc______________________________

Inflorescence (if present):
- Shape: Panicle, open and spreading, compressed, spikelike____________
- Length—average of 5______________________________
- Number of flowers per spikelet______________________________
- Color: ______________________________

Exercise 34.—*Identification of Seeds of Grasses and Legumes.*

Purpose: To familiarize students with common farm seeds.

Directions: After students have become familiar with the seeds of the grasses suggested in Exercise 33, mixtures of the seeds should be made and the students required to separate them. The same requirements may be made with regard to seeds of the following legumes: Alfalfa, sweet clover, red clover, alsike, white clover, bur clover, Japan clover, crimson clover, and yellow trefoil. It will be necessary to give special attention to seeds which look alike, such as alfalfa and sweet clover. A hand lens will be found useful in this work.

Record and *report:* Drawings of the seed magnified about 10 diameters should accompany a brief description of each variety.

Lesson 50.—*The Millets.*

Special references.—The following Farmers' Bulletins: 101, Millets; 168, Pearl Millet.

Lesson 51.—*Meadows.*

1. Management and care of natural meadows.
2. Soils and fertilizers.
3. Meadow mixtures.
4. Establishing and maintaining the meadows.

Lesson 52.—*Hay making.*

1. Time for cutting various forage crops.
2. Cutting and curing.
3. Storing.
4. Market hay.

Special references.—The following Farmers' Bulletins: 312, A Successful Southern Hay Farm; 508, Market Hay; 677, Growing Hay in the South for Market.

Lesson 53.—*Pastures.*

1. Management and care of natural pastures.
2. Soils and fertilizers.
3. Pasture mixtures.
4. Establishing and maintaining the pasture.

Special references.—

Permanent Pastures for the Cotton Belt, Office of Secretary of Agriculture. Special circular.

Meadows and Pastures, Farmers' Bulletin 66.

Lesson 54.—*Crops for Soiling and Silage.*

1. Crops suitable for soiling.
2. Crops suitable for silage.
3. Management of the crops.

Special references.—The following Farmer's Bulletins: 102, Southern Forage Plants; 147, Winter Forage Crops for the South; 300, Some Important Grasses and Forage Plants for the Coast Region.

Lesson 55.—*Rotation of Crops.*

1. History and development of crop rotation.
2. Purposes of crop rotation.

Illustrative material: Chart showing purposes of rotation.

Lesson 56.—*Rotation of Crops*—Continued.

1. Essentials of good rotations.
2. Plans for rotations.

Illustrative material: Maps of farms showing rotation plans.

Special references.—

Cropping Systems for Stock Farms. United States Department of Agriculture Yearbook. Separate, 456.

Planning a Cropping System. United States Department of Agriculture Bur. Pl. Indus. Bul. 102, pt. 3.

Practices in Crop Rotation. United States Department of Agriculture Yearbook, 1902.

Relations Between Rotation Systems and Insect Injury in the South. United States Department of Agriculture Yearbook. Separate, 561, 1911.

Lesson 57.—*Weeds.*

1. Definition of weeds.
2. Importance of weed study.
3. Classification.
4. Damage done by weeds.

LESSON 58.—*Weeds*—Continued.

1. Relation of weeds to cultivation.
2. How weeds spread.
3. Method of eradication.

Illustrative material: Charts showing how some weeds spread.

LESSON 59.—*Important Local Weeds.*

1. Their botany.
2. Methods of control.

Illustrative material: An herbarium of local weeds; a collection of seeds of noxious weeds.

Special references.—The following Farmers' Bulletins: 86, Thirty Poisonous Plants; 188, Weeds Used in Medicine; 279, A Method of Eradicating Johnson Grass; 368, The Eradication of Bindweed or Wild Morning Glory; 382, The Adulteration of Forage Plant Seeds; 464, The Eradication of Quack Grass; 545, Controlling Canada Thistles; 660, Weeds and How to Control Them.

EXERCISE 35.—*Collection and Study of Weeds.*

Purpose.—To familiarize students with the common noxious weeds.

Directions: Each student should be requested to collect and identify 10 weeds. It is preferable that these weeds be brought from the home farm and represent the weeds giving most trouble. If the students have had work in systematic botany a botanical key may be used for identification. Other students may use an illustrated weed manual. From the weeds collected specimens may be selected and mounted as a weed herbarium for the agricultural museum. Such an herbarium will be useful for identifying weeds in the future as well as for study when fresh specimens are not obtainable. Whenever possible a sample of ripe seed should accompany the dried plant.

Record and *report:* A brief description should be given of each weed with an explanation of why it is pernicious and how it may best be controlled. Wherever possible a drawing should be made of the plant when very young.

EXERCISE 36.—Testing farm seeds for impurities.

Purpose: To gain practice in the examination of purchased seed and further practice in the recognition of seeds of grasses, legumes, and weeds.

Directions: Samples of alfalfa, the clovers, and the grasses should be tested by each student for impurities. If the seed sold on the local market does not give the desired practice the instructor should make up mixtures of good seed containing foreign matter and seeds of weeds. Complete directions for this work may be obtained from Farmers' Bulletin 428, Testing Farm Seeds in the Home and in the Rural School.

Record and *report:* A record should be made of the impurities found in each sample which will form the basis of a report showing the relation of the foreign material to the value of the seed.

SUGGESTIONS FOR HOME PROJECTS—FIRST YEAR.

PRODUCTION PROJECTS.

The profitable production of one-half acre or more of one of the following crops: Corn, one of the sorghums, cane, tobacco, potatoes, sweet potatoes, cotton, peas, beans, peanuts, or any annual crop which may be sold for cash.

DEMONSTRATION PROJECTS.

In connection with or in addition to his production project the student may carry out one or more of the following demonstrations: (1) Trying out a crop new to the region, (2) a variety test, (3) working out a rotation, (4) a fertilizer test, (5) use of barnyard manure, (6) use of cover crops and green manures, and (7) improvement by seed selection.

LABORATORY EQUIPMENT FOR SOILS AND CROPS.

(Apparatus and material for 12 students.)

One torsion or Harvard trip balance. (A set of avoirdupois weights will be found useful along with the metric weights.)

One drying oven.

One soil auger.

Twelve alcohol lamps (if gas is not provided).

Twelve tripod lenses.

Four thistle tubes.

Four glass funnels.

Ten 1-inch glass tubes, 4 feet long, with two racks for holding five each.

Two dozen each of the following: Student-lamp chimneys, tin pie plates, paper pie plates, glass tumblers, one-half pint wide-mouthed bottles, quart fruit jars, quart tin cans, 4-inch flower pots, 8-inch flower pots, 8-inch flower pots and soil cans, 4 by 4 inches and 4 inches deep.

Four yards each of oilcloth, canton flannel, cheesecloth, and muslin.

The following boxes to be made by students: One dozen 12 by 12 inches, 8 inches deep; one dozen 12 by 12 inches, 6 inches deep; two dozen 14 by 12 inches, 4 inches deep.

One pound of paraffin and 2 pounds of formalin.

One-half pound of each of the following seeds for testing: Old wheat, fresh wheat, corn, peas, beans, and squash.

One hundred pounds each of clean sand and good loam.

Twenty-five pounds each of gravel, clay, leaf mold, and sawdust.

Ten pounds each of air-slaked lime and dry road dust.

One-fourth pound of lampblack.

Twelve feet of 3-foot wire fencing for corn racks.

Collections to show types and varieties of the following: Corn, small grains, sorghums, and cotton.

Bottles, vials and cardboard for mounting grains, grasses, legumes, and weeds (plants and seeds.)

Score cards for cereals, cotton, etc.

Hotbeds and cold frames or seed beds will be needed for Exercises 28 and 29.

An exhibit of commercial fertilizers and fertilizing materials with sufficient quantities of the latter for the practicum in home mixing.

Each student should have a laboratory notebook.

TEXTS AND REFERENCES FOR SOILS AND CROPS.[1]

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2. Burkett, C. W. and Poe, Clarence. Cotton. Garden City, N. Y.: Doubleday, Page and Co., 1906.
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4. Burkett, C. W. Soils. New York: Orange Judd Co., 1907.
5. Carleton, M. A. The Small Grains. New York: The Macmillan Co., 1916.
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8. Duggar, J. F. Southern Field Crops. New York: The Macmillan Co., 1911.
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11. Harris, F. S., and Stewart, George. The Principles of Agronomy. New York: The Macmillan Co., 1916.
12. Hitchcock, A. S. A Textbook of Grasses. New York: The Macmillan Co., 1914.
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16. Livingston, George. Field Crop Production. New York: The Macmillan Co., 1914.
17. Lyon, T. L., and Montgomery, E. G. Examining and Grading Grains. Boston: Ginn and Co., 1907.
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22. Piper, C. V. Forage Plants and Their Culture. New York: The Macmillan Co., 1915.
23. Sell, E. S. Agricultural Laboratory Manual—Soils, Boston: Ginn and Co., 1915.
24. Snyder, Harry. Soils and Fertilizers. New York: The Macmillan Co., 1914, 3d ed.
25. Thorne, C. E. Farm Manures. New York: Orange Judd Co., 1913.
26. Vivian, Alfred. First Principles of Soil Fertility. New York: Orange Judd Co., 1908.
27. Vorhees, E. B. Fertilizers. New York: The Macmillan Co., 1916 rev.
28. Whitson, A. R., and Walster, H. L. Soils and Soil Fertility. St. Paul, Minn.: Webb Publishing Co., 1912.
29. Wing, J. E. Alfalfa in America. Chicago. Sanders Publishing Co., 1912.
30. Wing, J. E. Meadows and Pastures. Chicago: Sanders Publishing Co., 1911.

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[1] These books are recommended by the Commission on Accredited Schools of the Southern States.

OUTLINE FOR ANIMAL HUSBANDRY—SECOND YEAR.

(One unit.)

TYPES AND BREEDS OF CATTLE.

(Nine lessons; six double periods for practical work.)

Reference: A Secondary Course in Animal Production, U. S. Dept. of Agriculture, Office of Expt. Stas. Circ. 100.

Illustrative material: Charts, pictures, and lantern slides showing types and breeds. Living specimens whenever convenient. (Visits should be made to near-by stock farms. A stereopticon will be found invaluable.)

LESSON 1.—*The Dairy Type.*

1. Purpose of the dairy cow.
2. Form and general appearance.
3. The score card for dairy cattle.
4. Importance of scales and Babcock test as an aid to judging dairy cattle.

Special reference: Judging the Dairy Cow as a Subject of Instruction in Secondary Schools, U. S. Dept. of Agriculture Bul. 434.

PRACTICUMS 1 and 2.—*Judging the Dairy Cow.*

LESSON 2.—*The Jersey.*

(*a*) Origin—history.
(*b*) Characteristics.
(*c*) Production.
(*d*) Official breed organization.

NOTE.—A similar outline may be adapted to all of the important breeds to follow.

LESSON 3.—*The Holstein and Guernsey.*

LESSON 4.—*Other Dairy Breeds.*

1. The Ayrshire.
2. Brown Swiss.

Special reference: Breeds of Dairy Cattle, Farmers' Bulletin 106.

PRACTICUM 3.—*Comparative Study of Dairy Breeds.*

LESSON 5.—*The Beef Type.*

1. Purpose of beef cattle.
2. Form and general appearance.
3. The score card for beef cattle.

PRACTICUM 4.—*Judging the Beef Type.*

LESSON 6.—*English Beef Breeds.*

1. The Shorthorn and Polled Durham.
2. The Hereford.

LESSON 7.—*Scotch Beef Breeds.*

1. The Aberdeen Angus.
2. The Galloway.
3. The West Highland.

LESSON 8.—*Dual-Purpose Cattle.*

1. The dual-purpose type.
2. The Shorthorn of this type.

3. The Red Polled.
4. The Devon.

PRACTICUM 5.—*Judging Dual-Purpose Cattle.*

LESSON 9.—*Market Classes and Grades of Cattle.*

1. Carcass beef—classes.
2. Beef cuts.
3. Beef products.

PRACTICUM 6.—*Judging Local Cattle by Comparison.*

TYPES AND BREEDS OF HORSES AND MULES.

(Seven lessons; four double periods for practical work.)

References.—

Breeds of Draft Horses, Farmers' Bul. 619.

Market Classes of Horses, U. S. Dept. of Agriculture, Bur. An. Indus. Bul. 37.

Selecting and Judging Horses for Market and Breeding Purposes, U. S. Dept. of Agriculture Yearbook, 1902.

Judging Horses as Subject of Instruction in Secondary Schools, U. S. Dept. of Agriculture Bul. 487.

LESSON 1.—*Types of Light Horses.*

1. Function of light horses.
2. Structure and conformation—study of score card.
3. The light harness type.
4. The saddle type.

LESSON 2.—*Breeds of Light Horses.*

1. The Thoroughbred.
2. The American trotter and pacer—Standard bred.
3. The American saddle horse.
4. Coach horses.

PRACTICUM 1.—*Judging Light Horses.*

LESSON 3.—*The Draft Type.*

1. Function of draft horses.
2. Structure and conformation—study of score card.
3. Development of draft type.

LESSON 4.—*Breeds of Draft Horses.*

1. The Percheron.
2. French draft.
3. The Belgian.

LESSON 5.—*Breeds of Draft Horses*—Continued.

1. The Shire.
2. The Clydesdale.
3. The Suffolk.

PRACTICUMS 2 AND 3.—*Judging Draft Horses.*

LESSON 6.—*The Jack and the Mule.*

1. Comparison of mule with the horse.
2. Importance of mules in the South.

LESSON 7.—*The Jack and the Mule*—Continued.

1. Breeds of jacks.
2. Conformation and type of jacks and mules.

PRACTICUM 4.—*Judging Jacks and Mules.*

TYPES AND BREEDS OF SHEEP.

(Three lessons; two double periods for practical work.)

References.—
Domestic Breeds of Sheep in America, U. S. Dept. of Agriculture Bul. 94.
Breeds of Sheep for the Farm, Farmers' Bul. 576.

LESSON 1.—*The Mutton Type.*

1. Relation of type to efficiency in mutton production.
2. The score card for mutton sheep.
3. Description of mutton type.
4. Market grades and classes.

PRACTICUM 1.—*Judging Mutton Sheep.*

LESSON 2.—*The Mutton Breeds.*

1. The Southdown.
2. The Shropshire.
3. The Hampshire.
4. The Suffolk Down.
5. The Oxford Down.
6. The Dorset.
7. The Cheviot.
8. The Cotswold.
9. The Lincoln.

PRACTICUM 2.—*A Study of Wool from Different Breeds and of the Different Market Classes.*

LESSON 3.—*Fine Wool Type and Breeds. Goats.*

1. Classes of merino sheep.
2. General conformation.
3. The American Merino.
4. The Delaine Merino.
5. The Rambouillet.
6. Goats.
   (*a*) The Angora.
   (*b*) Milch goats.

Special reference: The Angora Goat, Farmers' Bul. 573.

TYPES AND BREEDS OF SWINE.

(Six lessons; four double periods for practical work.)

LESSON 1.—*The Lard Type of Swine.*

1. Purpose and development of type.
2. Form and general appearance.
3. The score card for fat hogs.

PRACTICUM 1.—*Judging Fat Hogs.*

LESSON 2.—*The Bacon Type of Swine.*

(Same as for lard type.)

PRACTICUM 2.—*Judging Bacon Hogs.*

LESSON 3.—*Breeds of Swine.*

1. The Berkshire.
   (*a*) Characteristics and utility.
   (*b*) Origin and history.
   (*c*) The Berkshire in the United States.
   (Same outline for all important breeds of swine.)
2. The Poland China.

LESSON 4.—*Breeds of Swine*—Continued.

1. Chester White.
2. Duroc Jersey.

LESSON 5.—*Breeds of Swine*—Continued.

1. Hampshire.
2. Tamworth.
3. Large Yorkshire.
4. Any of the following breeds or others which may be of local importance: Small and middle Yorkshire, Mulefoot, Cheshire, Victoria, Essex.

LESSON 6.—*Market Classes and Grades of Swine.*

1. The swine market.
2. Grades of swine.
3. Swine products.

Special reference: Judging Swine as a Subject of Instruction in Secondary Schools, Agricultural Education Monthly, Vol. II, No. 7.

PRACTICUMS 3 AND 4.—*Judging Swine.*

IMPROVEMENT OF ANIMALS.

(Five lessons.)

References.—

Principles of Breeding and Origin of Domesticated Breeds of Animals, Separate from Twenty-seventh Report of Bureau of Animal Industry, 1910.

LESSON 1.—*Variation in Animals.*

1. Law of variation.
2. Sports and mutations.
3. Selection.
   (*a*) Natural.
   (*b*) Artificial.

LESSON 2.—*Heredity.*

1. Law compared with variation.
2. Mendel's law.
3. Cross breeding versus pure breeding.

LESSON 3.—*Prepotency.*

1. Value in breeding.
   (*a*) Prepotent individuals.
2. A study of pedigrees.
3. Registration of animals.

LESSON 4.—*Practical Problems in Breeding.*

1. Increasing variation.
2. Selection according to ideals.
3. Testing hereditary power.

LESSON 5.—*Improvement of Common Stock.*

1. Weeding out unprofitable individuals.
2. Use of pure-bred sires.
3. Cooperative breeding.
4. Cow-testing associations.

FEEDS AND FEEDING.

(Nine lessons.)

References.—

Farmers' Bulletin 22, The Feeding of Farm Animals.

The Use of Energy Values in the Computation of Rations for Farm Animals, U. S. Dept. of Agr., Bur. An. Indus. Bul. 459.

Illustrative material: Charts showing feeding standards, etc.; samples of feeds.

LESSON 1.—*Composition of Plants and Animals.*

1. Relation of animals to plants.
2. Elements and compounds.
3. Composition of plants.
4. Composition of animals.

LESSON 2.—*Nutrients.*

1. Carbohydrates.
    (*a*) Nature.
    (*b*) Sources.
2. Proteids.
    (*a*) Nature.
    (*b*) Sources.
3. Fats.
    (*a*) Nature.
    (*b*) Sources.
4. Water and mineral matter.

LESSON 3.—(*a*) *Digestion.*

1. Nature of the process.
2. Organs.
3. Importance of normal function.

(*b*) *Assimilation*, (*c*) *Excretion.*

(Same as for digestion.)

LESSON 4.—*Function of Nutrients.*

1. Carbohydrates.
2. Proteids.
3. Fats.
4. Water and minerals.

LESSON 5.—*Feeding Standards.*

1. The nutritive ratio.
2. Comparison of standards.
3. Exercises in determining ratio.

LESSON 6.—*Roughages.*

1. Place in ration.
2. Classes and composition.
3. Importance of succulence.

LESSON 7.—*Concentrates.*

1. Place in ration.
2. Classes and composition.

LESSON 8.—*Purposes in Feeding.*

1. Maintenance.
2. Growth and development.
3. Milk production.
4. Fattening for market.

LESSON 9.—*Exercises in Compounding Rations.*

For different classes of animals for purposes given in Lesson 8.

CARE AND FEEDING OF DAIRY CATTLE.

(Seven lessons.)

References.—

Special Bulletins of the Office of the Secretary of Agriculture relative to Dairying in the South.

The Dairy Herd, Its Formation and Management, Farmers' Bulletin 55.

Farmers' Bulletin 743, The Feeding of Dairy Cows.

LESSON 1.—*Management of Breeding Animals.*

1. Development of the heifer.
2. Care and management at calving.
3. Development of the dairy bull.
4. Care and management of the bull.

LESSON 2.—*Care and Feeding of the Calf.*

1. Feeding milk.
2. Necessary equipment.
3. Importance of cleanliness.
4. Ration for development.

Special reference.—Farmers' Bulletin 777, Feeding and Management of Dairy Calves and Young Dairy Stock.

LESSON 3.—*Care and Feeding in Summer.*

1. Important considerations.
   (*a*) Fresh water.
   (*b*) Shade.
   (*c*) Protection from pests.
2. Pastures.
3. Soiling.

LESSON 4.—*Care and Feeding in Winter.*

1. Important considerations.
   (*a*) Water supply.
   (*b*) Fresh air.
   (*c*) Warmth and protection from drafts.
   (*d*) Dry quarters.
   (*e*) Sanitation of the stable.
   (*f*) Exercise.
2. Roughages in the ration.
3. Concentrates in the ration.
4. Keeping the cows clean.

LESSON 5.—*Making and Feeding of Silage.*

1. Value of silage in feeding.
2. Kinds of silage.
3. Filling the silo.
4. Feeding silage to cows.

Special references.—The following Farmers' Bulletins: 292, Cost of Filling Silos; 578, Making and Feeding of Silage.

LESSON 6.—*The Dairy Barn.*

1. Location.
2. Relation of size of barn to size of herd.
3. Important requisites:
   (*a*) Ventilation.
   (*b*) Sunlight.
   (*c*) Sanitation.
   (*d*) Comfort.
   (*e*) Convenience.
4. Relation of cost to service.
5. Types and plans.

Special reference.—Individual plans furnished by Dairy Division, U. S. Dept. Agr.

LESSON 7.—*The Silo.*

1. Location.
2. Types and materials.
3. Construction.
4. Relation of capacity to size of herd.

Special reference: Farmers' Bulletin 589, Homemade Silos. Individual plans from Dairy Division, U. S. Dept. Agr.

CARE AND FEEDING OF BEEF CATTLE.

(Five lessons.)

References.—

The following Farmers' Bulletins: 183, Meat on the Farm; 580, Beef Production in the South; 635, Cottonseed Meal for Feeding Beef Cattle.

Fattening Cattle in Alabama, U. S. Dept. of Agriculture Bul. 110.

LESSON 1.—*A Survey of Modern Beef Production.*

1. History of the beef-cattle industry.
2. Present status of the industry.
3. Beef making in the South.

LESSON 2.—*Care and Feeding of Young Stock.*

1. Handling of breeding stock.
2. Care and development of young stock.
3. Veal production.
4. Baby beef.

LESSON 3.—*Summer Feeding.*

1. Pastures.
2. Supplementary feeding.

LESSON 4. *Winter Feeding.*

1. The feed lot.
2. Shelter.
3. Feeds and feeding.

LESSON 5.—*Finishing and Marketing.*

1. Fattening rations.
2. Economics of beef production.
3. Marketing on the hoof.
4. Home slaughtering.

CARE AND FEEDING OF MULES AND HORSES.

(Five lessons.)

References.—

Principles of Horse Feeding, Farmers' Bul. 170.

Also special bulletin of the Office of the Secretary of Agriculture on same subject.

LESSON 1.—*Management of Breeding Animals.*

1. The brood mare.
2. The stallion and jack.

LESSON 2. —*The Care and Feeding of Colts.*

1. The sucking colt.
2. Weaning.
3. Feeding for development.
4. Protection from injury.

LESSON 3.—*Training the Colt.*

1. Halter breaking—teaching the foal to lead.
2. Fitting the harness.
3. Training to drive.
4. Breaking to ride.
5. Importance of careful training.

Special reference: Colts, Breaking and Training, Farmers' Bul. 667.

LESSON 4.—*Feeding Mules and Horses at Work.*

1. Food requirements for work.
2. Relation of feeding to capacity.
3. Methods of feeding.

LESSON 5.—*Care and Management of Mules and Horses.*

1. Watering and salting.
2. Grooming.
3. Use of blankets.
4. Care of the feet.
5. Driving and riding.

CARE AND FEEDING OF SHEEP.

(Three lessons.)

References.—

Producing Sheep on Southern Farms, Special Bulletin, Office of Secretary of the Department of Agriculture.

The following Farmers' Bulletins: 49, Sheep Feeding; 96, Raising Sheep for Mutton; 652, The Sheep Industry as Menaced by the Dog.

LESSON 1.—*Place of Sheep on the Farm.*

1. History and development of the sheep industry.
2. Opportunities in sheep husbandry.
3. Sheep on southern farms.
4. The dog menace.

LESSON 2.—*Production of Mutton.*

1. Care of sheep at lambing time.
2. Feeding for development.
3. Summer and winter care.
4. Fattening sheep.
5. Winter lambs.

LESSON 3.—*Production of Wool.*

1. Relation to mutton production.
2. Dipping sheep.
3. Shearing sheep.
4. Sheep barns.

CARE AND FEEDING OF SWINE.

(Five lessons.)

References.—

The following Farmers' Bulletins: 205, Pig Management; 438, Hog Houses; 566, Boys' Pig Clubs; 411, Feeding Hogs in the South.

Hog Raising in the South, Office of Secretary of Agriculture Circular 30.

How Southern Farmers May Get a Start in Pig Raising, Office of Secretary of Agriculture Special Circular.

LESSON 1.—*Possibilities in Pigs.*

1. Swine as economical producers of meat.
2. Consumers of farm waste.
3. Hogs following cattle.
4. How boys may get a start.

LESSON 2.—*Management of Breeding Animals.*

1. The brood sow.
2. The boar.
3. Farrowing.

LESSON 3.—*Care and Feeding of Young Stock.*

1. Before weaning.
2. After weaning.

LESSON 4.—*Fattening for Market.*

1. Costs of raising pigs.
2. Relation of cost to age.
3. Winter feeding and care.
4. Finishing for market.
5. Home curing of meat.

LESSON 5.—*Hog Houses and Yards.*

1. Importance of sanitation, dryness, ventilation, light, and warmth.
2. Relation of cost to economical production.
3. Plans of various types.

MILK AND ITS PRODUCTS.

(Ten lessons; six double periods for practice.)

References.—

Special Bulletins of the Office of the Secretary of Agriculture. Also the following Farmers' Bulletins: 349, The Dairy Industry in the South; 490, Bacteria in Milk; 541, Farm Butter Making; 602, Production of Clean Milk.

LESSON 1.—*Secretion of Milk.*

1. Nature of milk.
2. Organs of secretion.
3. Factors influencing secretion.

LESSON 2.—*Composition of Milk.*

1. Average composition.
2. Variations and causes.
3. Nature of constituents.
4. Relation to feeding.

LESSON 3.—*Fermentation Changes in Milk.*

1. Kinds.
2. Causes of fermentation.
3. Nature of the process.
4. Control of fermentation.

LESSON 4.—*Production of Clean Milk.*

1. Prevention of undesirable flavors—relation to feeding.
2. Sanitation in the stable—control of odors.
3. Sanitation in the milk room and dairy.
4. Clean milking.

LESSON 5.—*Separation and Handling of Cream.*

1. Gravity separation.
2. The centrifugal separators.
3. Care and use of separators.
4. Factors influencing per cent of fat.
5. Handling cream.

LESSON 6.—*Testing Milk and Products.*

1. History of milk testing.
2. The Babcock test—Principles.
3. Value to the industry—Practical application.
4. Tests for sediment and specific gravity.

Special reference: Complete directions with a list of equipment needed will be found in Chemical Testing of Milk and Cream, U. S. Dept. of Agr., Bur. An. Indus. Doc. A7.

PRACTICUMS 1 AND 2.—*Care and Use of Separators.*

PRACTICUMS 3 AND 4.—*Testing Whole Milk.*

PRACTICUM 5.—*Testing Skim Milk.*

PRACTICUM 6.—*Testing Cream.*

LESSON 7.—*Butter Making.*

1. Ripening of cream.
2. Churning, salting, and working.
3. Printing and marketing butter.

Special reference: Illustrated Lecture on How to Make Good Farm Butter, U. S. Dept. of Agr., Syllabus 19.

LESSON 8.—*Cheese Making.*

1. Types of cheese for the farm.
2. Making cheese on the farm.
3. Types of market cheese.

LESSON 9.—*Milk for the Market.*

1. Developing a local trade.
2. Milk shipments.
3. Essentials toward success.

LESSON 10.—*The Farm Dairy House.*

1. Plans and construction.
2. Equipment and arrangement.
3. Water supply and methods of heating.
4. Cooling facilities.
5. Sanitation.

Special reference: Farmers' Bulletin 689, Plan for a Small Dairy House. Individual plans furnished by the Dairy Division, U. S. Dept. Agr.

POULTRY.

(Fifteen lessons; six double periods for practical work.)

References—

Suggestions on Poultry Raising for the Southern Farmer, Special Bulletin, Office of Secretary of Agriculture. Also the following Farmers' Bulletins: 51, Standard Varieties of Chickens; 64, Ducks and Geese; 200, Turkeys; 287, Poultry Management; 445, Marketing Eggs; 452, Capons; 530, Important Poultry Diseases; 528, Hints to Poultry Raisers; 562, Boys' and Girls' Poultry Clubs; 574, Poultry Houses; 585, Natural and Artificial Incubation of Hens' Eggs; 594, Shipping Eggs by Parcel Post; 624, Natural and Artificial Brooding of Chickens; 682, Simple Trap Nest for Poultry; 697, Duck Raising; 767, Goose Raising.

LESSON 1.—*Fowls: Origin and Place on the Farm.*

1. Origin of the domestic fowl.
2. Status of the poultry industry.
3. Possibilities in poultry.

LESSON 2.—*Classification of Fowls.*

1. Definition of terms: Class, breed, variety, strain.
2. Classification based on country of origin.
3. Classification based on utility.
4. Classification of American standard of perfection.

Illustrative material for lessons 2, 3, 4, and 5: Charts, pictures, and lantern slides showing types and breeds of fowls.

LESSON 3.—*Utility Types.*

1. Meat type.
2. Egg type.
3. General-purpose type.

LESSON 4.—*American and English Breeds.*

1. The Plymouth Rock.
    (*a*) Characteristics of breed.
    (*b*) Varieties.
2. The Wyandotte.
3. The Rhode Island Red.
4. The Orpington.
5. The Dorking.

LESSON 5.—*Asiatic, Mediterranean, and Other Breeds.*

1. The Brahmas.
2. The Langshans.
3. The Leghorns.
4. The Minorcas.
5. Hamburgs, Anconas, Campines, Buttercups, and any other breeds of local importance.

Special reference: Lessons on Poultry for Rural Schools, United States Department of Agriculture Bulletin 464.

PRACTICUMS 1 and 2.—*Judging Fowls.*

PRACTICUMS 3 and 4.—*Study and Operation of Incubator.*

PRACTICUM 5.—*Testing and Grading Eggs.*

PRACTICUM 6.—*Preserving Eggs.*

LESSON 6.—*Natural Incubation and Brooding.*

1. Comparison of the two systems.
2. Setting the hen.
3. Care of the setting hen.
4. Management of hen and chicks.

LESSON 7.—*Artificial Incubation.*

1. Principles upon which incubator is constructed.
2. Types of incubators.
3. Incubator houses and cellars.
4. Operation of the incubator.
5. Development of the embryo.

LESSON 8.—*Artificial Brooding. Rearing Chicks.*

1. Removal from incubator.
2. Construction and management of brooder.
3. Feeding and care of chicks in brooder.
4. Brooder houses.
5. Care and feeding of young stock.

LESSON 9.—*Egg Production.*

1. The commercial egg farm.
2. Selection for egg production.
3. Feeding the layers.
4. Eggs for market *v.* eggs for hatching.
5. Securing eggs in winter.

LESSON 10.—*Poultry for Market.*

1. Production of broilers.
2. Production of roasters.
3. Killing and dressing.

LESSON 11.—*Poultry Houses and Yards.*

1. Essentials to be secured.
2. Relation of cost to economic production.
3. Building plans.
4. Equipment.
5. Systems of yarding.

LESSON 12.—*Vermin and Their Control. Diseases.*

1. Hygiene and sanitation—value of prevention.
2. Common diseases and their remedies.
3. Poultry parasites.
4. Other enemies of poultry.

LESSON 13.—*Marketing Poultry and Products.*

1. General principles involved.
2. Breeding stock.
3. Market poultry.
4. Eggs for hatching.
5. Market eggs.

LESSON 14.—*Ducks and Geese.*

1. Requirements.
2. Breeds and varieties.
3. Care and management.

LESSON 15.—*Turkeys and Guineas.*

1. Requirements.
2. Breeds and varieties.
3. Care and management.

BEES.

(Five lessons.)

References.—

The following Farmers' Bulletins: 442, Bee Diseases; 447, Bees; 503, Comb Honey; 653, Honey and Its Uses in the Home; 695, Outdoor Wintering of Bees.

Illustrative material: An observation hive of bees; an exhibit of apiary equipment.

LESSON 1.—*Natural History of the Honey Bee.*

1. Life history and structure.
2. Habits—hive activities.
3. Races of bees.
4. Honey plants.

LESSON 2.—*Modern Apiary Equipment.*

1. Location of the apiary.
2. The modern hive.
3. Other equipment.

LESSON 3.—*Manipulation of Bees.*

1. Handling of hives and combs.
2. Hiving a swarm.
3. Transferring.
4. Uniting.
5. Introduction of queen.

LESSON 4.—*General Management of Bees.*

1. Winter management and feeding.
2. Spring management.
3. Prevention of swarming.
4. Artificial swarming.
5. Treatment of disease.
6. Prevention of robbing.

LESSON 5.—*Production and Marketing of Honey.*

1. Producing comb honey.
2. Producing extracted honey.
3. Marketing honey.
4. Beeswax.

DISEASES OF ANIMALS.

(Ten lessons.)

References.—

Diseases of Cattle, Diseases of the Horse, U. S. Dept. of Agriculture. Also the following Farmers' Bulletins: 152, Scabies of Cattle; 206, Milk Fever and Its Treatment; 351, The Tuberculin Test; 350, Dehorning of Cattle; 379, Hog Cholera; 439, Anthrax; 449, Rabies; 479, Tuberculosis; 480, Disinfecting Stables; 540, The Stable Fly; 569, Texas Fever; 603, Arsenical Cattle Dips; 639, Eradication of the Cattle Tick Necessary for Profitable Dairying in the South.

Blackleg: Its Nature, Cause, and Prevention, U. S. Dept. of Agriculture, Bur. An. Indus. Circ. 31.

Foot and Mouth Disease, U. S. Dept. of Agriculture, Bur. An. Indus. Circ. 141.

How to Get Rid of Cattle Ticks, U. S. Dept. of Agriculture, Bur. An. Indus. Circ. 97.

LESSON 1.—*Unsoundness in Horses.*

1. Feet and leg troubles.
2. Harness troubles.
3. Other external ailments.

LESSON 2.—*Practicum—Examining Horses or Mules for Unsoundness.*

LESSON 3.—*Causes of Disease.*

1. Meaning of disease.
2. Relation to feeding, care, and management.
3. Value of inherited vigor and resistance.

LESSON 4.—*Parasites Causing Disease.*

1. Bacteria and disease.
2. Disease carriers.
3. Other parasites.

LESSON 5.—*Preventive Measures.*

1. Maintaining bodily vigor.
2. Sanitation.
3. Immunity by inoculation.

LESSON 6.—*Some Common Ailments and Their Treatment.*

1. Wounds and their treatment.
2. Bloating and colic.
3. Milk fever.
4. Blackleg.

LESSON 7.—*Common Ailments*—Continued.

1. Foot-and-mouth disease.
2. Rabies, tetanus, and actinomycosis.
3. Glanders.
4. Charbon and other diseases of local importance.

LESSON 8.—*Hog Cholera.*

1. Importance.
2. Cause.
3. Diagnosis.
4. Treatment.

LESSON 9.—*Texas Fever.*

1. Importance.
2. Cause.
3. Diagnosis.
4. Treatment.
5. Control of tick.

LESSON 10.—*Tuberculosis.*

1. Importance.
2. Cause.
3. Diagnosis.
4. Treatment.
5. Relation to human health.

SUGGESTIONS FOR HOME PROJECTS IN ANIMAL HUSBANDRY.

Care of calves on personal account.
Care and feeding of one or more cows for one year.
Keeping a dairy herd record for one year.
Developing a local milk or butter trade.
Production of baby beef.
Fattening cattle for the market.
Developing swine for breeding.
Feeding swine for pork production.
Care of sheep on personal account.
Care of sheep for share of increase.
Care and training of colts.
Care and management of team.
Care and management of poultry.
Handling bees on personal account.

ACCEPTABLE SUBSTITUTES FOR PROJECTS.

Work on general stock farm.
Work on dairy farm.
Work on poultry farm.
Work in apiary.

EQUIPMENT FOR ANIMAL HUSBANDRY.

A stereopticon with sets of lantern slides showing types and breeds of farm animals and poultry.

Score cards for use in judging.

An exhibit of commercial feeds.

A Babcock testing outfit.

A separator, churning outfit, and such other dairy equipment as may be obtained.

An incubator, a brooder, and such other poultry equipment as may be obtained.

A poultry plant at the school will be found invaluable, not only in teaching poultry husbandry but also in working out and applying general principles relating to the breeding, feeding, and general care of farm animals.

A stand of bees, preferably in an observation hive. Such apiary equipment as may be obtained.

TEXTS AND REFERENCES FOR ANIMAL HUSBANDRY.

The following list of books is recommended by the Commission on Accredited Schools of the Southern States and is published here simply for the convenience of teachers.

1. American Standard of Perfection. Mansfield, Ohio: American Poultry Association, 1915, new ed.
2. Comstock, A. B. How to Keep Bees. Garden City, N. Y.: Doubleday, Page and Co., 1905.
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4. Craig, J. A., and Marshall, F. R. Sheep Farming. New York: The Macmillan Co., 1913.
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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 522

Joint Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief
and the
Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C. ▼ May 18, 1917

CHARACTERISTICS AND QUALITY OF MONTANA-GROWN WHEAT

By

LEVI M. THOMAS, Assistant in Grain Standardization

CONTENTS

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CHARACTERISTICS AND QUALITY OF MONTANA-GROWN WHEAT.[1]

By Levi M. Thomas, *Assistant in Grain Standardization.*

CONTENTS.

INTRODUCTION.

Wheat production in Montana has shown a great increase during the past five or six years, due to rapid settlement, and a constantly increasing volume of wheat from this State is finding its way to the eastern and likewise to the far western grain markets. Although a small quantity of this wheat has been received at the eastern markets for several years, yet among many millers and wheat buyers it still retains the status of a "newcomer," and its reputation as to milling quality is largely dependent upon hearsay. Undoubtedly, the comparatively

[1] The work covered by this bulletin was done under the direction of Dr. J. W. T. Duvel, in charge of the Office of Grain Standardization of the Bureau of Plant Industry. Since August 18, 1916, the grain-standardization work of the Department of Agriculture has been administered jointly by the Office of Markets and Rural Organization and the Bureau of Plant Industry in connection with the administration of the United States Grain Standards Act.

This investigation was initiated by Messrs. L. A. Fitz and C. H. Bailey, formerly of the Office of Grain Standardization. Mr. Oliver M. Holmes, of the Chamber of Commerce of Great Falls, Mont., and Mr. E. C. Russell, of Lewistown, Mont., assisted in securing suitable wheat samples, as did also Director F. B. Linfield and Messrs. Alfred Atkinson and J. B. Nelson, of the Montana Agricultural Experiment Station. The milling studies were carried on in cooperation with the North Dakota Agricultural Experiment Station, with the special assistance of Prof. E. F. Ladd and Messrs. W. L. Stockham and Thomas Sanderson.

Note.—This bulletin is intended for farmers in Montana and adjoining States and for grain buyers throughout the country.

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low prices that have been paid for wheat from this source in the past have been due largely to the lack of information as to its true character and quality as a milling wheat. This explanation is only reasonable in view of the fact that the demand for these wheats is constantly increasing as they become better known. The history of these wheats is but a repetition of that of any new raw material that appears upon the market. There is at first an apparent discrimination against it, largely because it has not yet established a reputation, and the manufacturer is loath to make use of it in any great quantity until its character and fitness for use have been ascertained. Under such conditions the demand for the product is weak and the price is relatively low. Several factors have tended to emphasize this condition as related to Montana wheats. One of these is the very wide range in character and quality that exists between the various types of wheat grown within the State. For example, the low-gluten, starchy, white wheats, such as the Club varieties, may be found growing in a field adjacent to one of Fife wheat reputed to have the combination of such qualities as make it supreme for the production of a bread flour. Aside from this, there is a wide range in climatic conditions within the borders of the State, and complications are further augmented by the introduction of irrigation. That the use of irrigation water causes deterioration in the milling of wheat, especially of those factors spoken of as "strength," which are so desirable in bread flours, is quite generally claimed by millers and is upheld by the investigations of the Utah Agricultural Experiment Station,[1] where it was found that irrigation caused a decrease in protein content, accompanied by a decrease in "baking strength;" and, further, the extent of the variation seems to be in a measure proportional to the amount of irrigation water used.

FUTURE OF WHEAT PRODUCTION IN MONTANA.

That Montana is to become one of the most important wheat-producing States is scarcely to be doubted when one considers the record of the past few years and the marvelous possibilities of this untried State. The 1910 census placed the wheat acreage in 1909 at 258,000, while the estimated acreage for 1912 was 803,000, an increase of 211 per cent in four years.[2] The crop of 1914 covered 910,000 acres. The total wheat production in 1912 was more than 19 million bushels, three times as great as the production in 1909, when it amounted to about 6 million bushels. Figure 1 is a map made up

[1] Stewart, Robert, and Hirst, C. T. The chemical milling and baking value of Utah wheats. Utah Agr. Exp. Sta. Bul. 125, p. 111–150. 1913.

Widtsoe, J. A., and Stewart, Robert. The chemical composition of crops as affected by different quantities of irrigation water. Utah Agr. Exp. Sta. Bul. 120, p. 201–240. 1912.

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[2] U. S. Department of Agriculture, Bureau of Statistics, Crop Reporter, v. 14, No. 12, sup., p. 99. 1912.

from the 1910 census reports, illustrating the distribution of the 1909 wheat crop in Montana. Figure 2 shows the sources of the samples secured for this investigation.

MARKETING CONDITIONS IN MONTANA.

The marketing and selling of wheat in Montana are surrounded by many seeming and real abuses. Wheat classification and grading are most confused on account of their variability. Wheat prices are based upon Minneapolis quotations, less the freight, the commission, and the margin that the local grain buyer considers necessary to cover the cost of handling and net himself a profit.

The fact that at many shipping points the volume of wheat is yet very small adds materially to the unit cost of handling, for the quan-

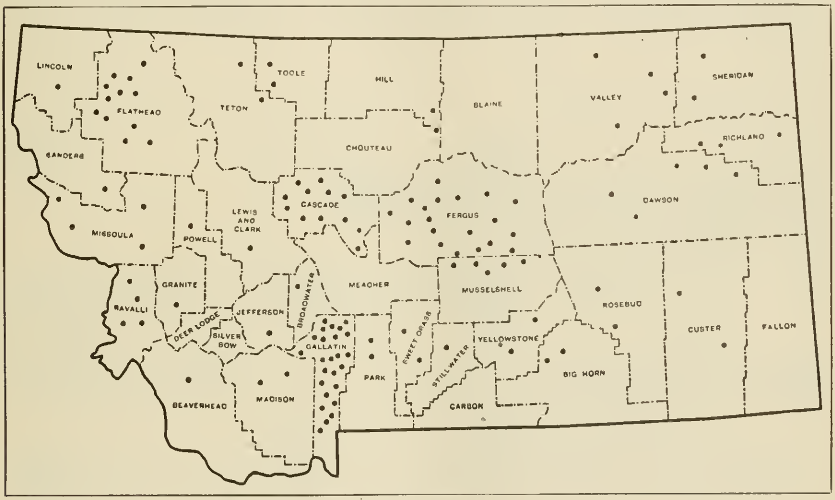


FIG. 1.—Outline map of Montana, showing the districts where wheat is produced. (From the 1910 census.) Each dot represents 50,000 bushels.

tity of grain received does not justify the building of elevators and warehousing facilities, and consequently the wheat must be handled by expensive man-power methods. At other points, where elevators have been built, the volume of grain is not sufficient to invite competition, or even in some cases to pay the expenses of the operation of the warehouse unless the grain is bought on a comparatively high margin.

The confusion that exists as to the classification of Montana wheat is largely dependent upon three factors, which may be summarized as follows:

(1) The fact that wheat of many varieties belonging to five distinct groups is grown within the borders of the State.

(2) The existence of several poorly defined systems of classification and grading.

(3) Varied environmental conditions within the State influencing the character of the grain, of which irrigation is probably the most important.

VARIETIES AND TYPES OF WHEAT GROWN IN MONTANA.

As has been said, the wheat grown in Montana may be divided into five distinct types and groups. The first and most important is the hard red winter wheat of the Turkey type. The estimates of the Bureau of Statistics for 1912 show that winter wheat constitutes about 60 per cent of the wheat grown in the State, and a very large proportion of this is undoubtedly of the type generally known as Turkey.

Hard spring wheat of the Fife or Bluestem groups is second in importance. The principal varieties are Red Fife and Bluestem.

Just what is the relative importance as to the quantity grown of the three remaining types would be difficult to ascertain. Some durum wheat is grown, probably the greater proportion in the eastern part

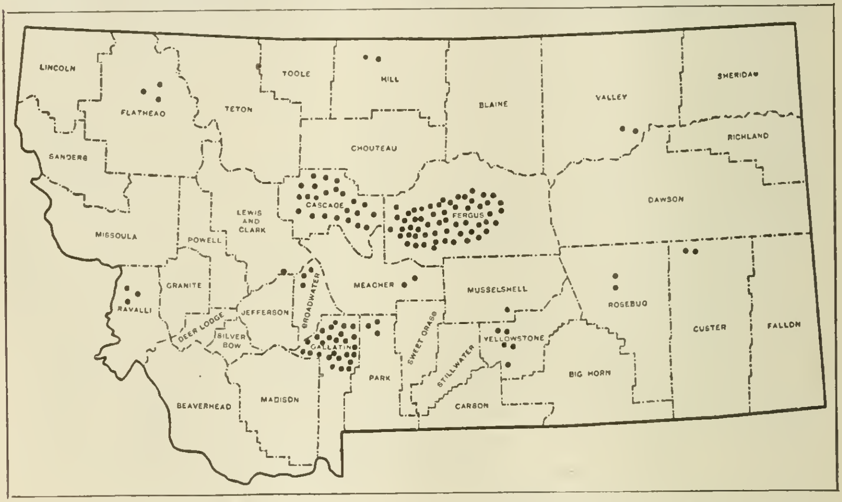


FIG. 2.—Outline map of Montana, showing the districts where the wheat samples discussed in this bulletin were obtained.

of the State, where the growing of winter wheat has not been demonstrated to be a success.

Soft wheats, both red and white, are grown in uncertain quantities, especially in the irrigated sections, such as the Gallatin Valley. The soft red wheat consists largely of the type known as Crail Fife. Other varieties, such as Velvet Chaff (winter), Galgalos, and Pringle Champlain, the latter of which seems to be of a semihard type, are grown to a very limited extent.

Varieties of white wheat, which are variously designated as Little Club, Fall Club, Spring Club, and Sonora, constitute the fifth class.

GRADING MONTANA WHEAT.

As has already been said, the grading of Montana wheats is very variable, and especially is this true at the primary markets. In certain localities an attempt is made to classify and grade the wheat in accordance with the practices of the Minnesota State Grain Inspection Department. In others, a very different classification has been adopted, which system is fathered largely by elevator companies that have connections with Montana flour mills. Where sufficient grain is grown to invite competition in the grain-handling business, grading conditions are generally much better than where there is but one buyer. For instance, in several localities where there has been but one grain buyer, winter wheat, whether of poor or good quality, has been bought at uniform prices and no attempt made at grading, a practice that is manifestly unfair and offers encouragement to slipshod methods of harvesting and marketing grain. Table I gives in outline form a summary of these general commercial practices.

TABLE I.—*Common varieties and types of Montana wheats, with their commercial classification.*

Variety.	General type.	Commercial classification.
Winter wheat:		
Turkey	Hard red winter	Local, higher grades as 1 and 2 Turkey; lower grades as western red (grades 1, 2, and 3); starchy samples may not be graded better than 1 western red. Minnesota classification as No. 1, 2, and 3 hard winter; very poor quality wheat may be classed as western red; followed locally in some instances.
Crail Fife	Soft red or semi-hard red winter.	Local and Minnesota classification, as western red.
Velvet Chaff (winter)		
Fall Club and other winter varieties of white wheat.	Soft white	Western white.
Spring wheat:		
Fife, Bluestem, and all common varieties and strains of northern-grown spring wheat.	Hard red spring	Local, varies; higher quality grades No. 1, 2, and 3 northern; lower quality wheat, including starchy lots, may be classed as western red. Minnesota classification, as northern spring wheat.
Pringle Champlain	Hard red or semi-hard spring.	Varies; western and northern spring.
Galgalos	Soft red	Varies; western, northern spring, and durum.
Spring Club	Soft white	Western white.
Stanley, spring		
Other spring-sown white wheats.		
Arnautka	Hard, flinty	Durum; grades 1, 2, and 3 durum; local and terminal market classification probably identical.
Kubanka		
Pelissier, spring		
Other durum varieties		

The most uniform classification is followed with hard spring wheat. Generally the classification and division into the northern spring grades are much the same as those promulgated by the Minnesota State Grain Inspection Department. Good and fair quality of hard winter wheat is bought as No. 1 and No. 2 Turkey. Hard winter wheat, not thought to be good enough for these grades, is bought as western red wheat and graded No. 1, 2, or 3, according to quality. The western red grades afford a convenient place for such red wheats as for various reasons are not considered good enough for the northern spring or Turkey (hard winter) grades. This is also true for the soft red wheats, such as Crail Fife.

All white wheats are conveniently grouped as western white, in accordance with the general practice throughout the country. Durum wheat receives the usual separate classification.

WHEAT QUALITY.

Before proceeding with a discussion of the results of this investigation, some of the factors relating to milling quality will be considered. Accepting the proposition that the only sound basis for the determination of the quality of wheat is by a consideration of its fitness for the manufacture of flour and by a study of the characteristics of the flour, special emphasis has been laid upon investigations involving milling and baking tests.

The term "milling quality" has a varied meaning, and in speaking of wheat of high milling quality two millers may have very different standards in mind. Broadly speaking, any wheat which will yield a high percentage of white, sound flour is of good milling quality. But this definition holds only when wheat flour is considered as flour and it is not recognized that there is a remarkable variation in the characteristics of flour made from different types of wheat. The manufacturer of a cracker or pastry flour desires a wheat which is preferably low in protein, rather than glutinous, and he finds that the soft red or white wheats are well suited to his needs. In selecting he is chiefly concerned in securing wheat of these types that is plump and sound and that will yield a high percentage of white flour.

On the other hand, a miller who is making what is primarily a bread flour desires a hard glutinous wheat, the flour from which has a combination of qualities that under the proper treatment will produce a large light loaf of bread of even porosity or texture. Such flour is said to be of high baking strength. Because of the demand made by the baker for "strong" flour, the miller is often willing to sacrifice a little on flour yield to secure wheat the flour from which has this desirable characteristic. Another desired flour quality from the bakers' standpoint is water absorption, or the amount of water required by the flour to mix the dough to a standard consistency. Importance is attached to this, largely because of the relationship which is borne by this factor to yield of bread per unit of flour.

To recapitulate, from the standpoint of the miller, a high-grade milling wheat for bread making must yield a high percentage of white (color) merchantable (sound) flour of high baking strength (loaf volume and texture), which is capable of giving a good yield of bread per unit of flour by virtue of its ability to absorb water and retain the same (water absorption) during baking. Hard spring and hard winter wheats are best suited for the production of flour of this kind, but, on the other hand, flour from these types of wheat is not so well adapted for the making of crackers or pastry products.

It is possible that still another definition of a good milling wheat might be offered by a miller producing semolina for the manufacture of macaroni and other edible pastes. He desires a wheat which will produce a hard granular semolina containing a high percentage of gluten or gluten proteids, which are responsible for the peculiar qualities necessary in the manufacture of such products. He also desires a rich creamy or yellow product. Durum wheat offers a combination of qualities that make it especially desirable for such purposes.

COLOR OF FLOUR AND BREAD.

The importance attached to color of flour is dependent upon the natural demand of the consumer of white bread. The factors of color and flour yield bear a direct relationship to each other, the former being in a sense a limiting factor of the second. Were it not for the sacrifice of color, wheat could be ground much closer and the flour yield considerably increased without the flour suffering a marked deterioration of other qualities. In a study of the tables that follow, the color score of the bread and the flour yield or percentage of flour should be considered together.

WATER ABSORPTION.

The importance of the water absorption of a unit quantity of flour and its direct relationship to yield of bread have been discussed in the consideration of milling quality. It suffices to say that this factor is of considerable commercial importance. It is generally highest in the more glutinous flours and lowest in the soft, starchy types. In the following tables water absorption is expressed as the percentage of water used. A brief statement will explain the meaning of this term. In the baking tests 340 grams of flour are used in each loaf. If, in mixing, the equivalent of 170 grams of water were used, the absorption would be expressed as 50 per cent.

LOAF VOLUME AND TEXTURE.

In the baking tests which are reported herein, 340 grams of flour were used in each instance and the measured volume of the resultant loaf is expressed in cubic centimeters. Loaf volume, more than any other one factor, is considered indicative of strength in flour, but it should always be considered in connection with the texture score, which is based upon the size and number of air cells and the character of the cell walls.

HARD WINTER WHEAT.

As has been said, the wheat most extensively grown in Montana is hard winter wheat of the type known as Turkey. Although the production of spring wheat of the harder varieties has increased very rapidly during the past few years, the production of winter wheat has more than kept pace with this increase. Because of its relatively greater importance, a far more complete study has been made of Turkey winter than of the other wheats.

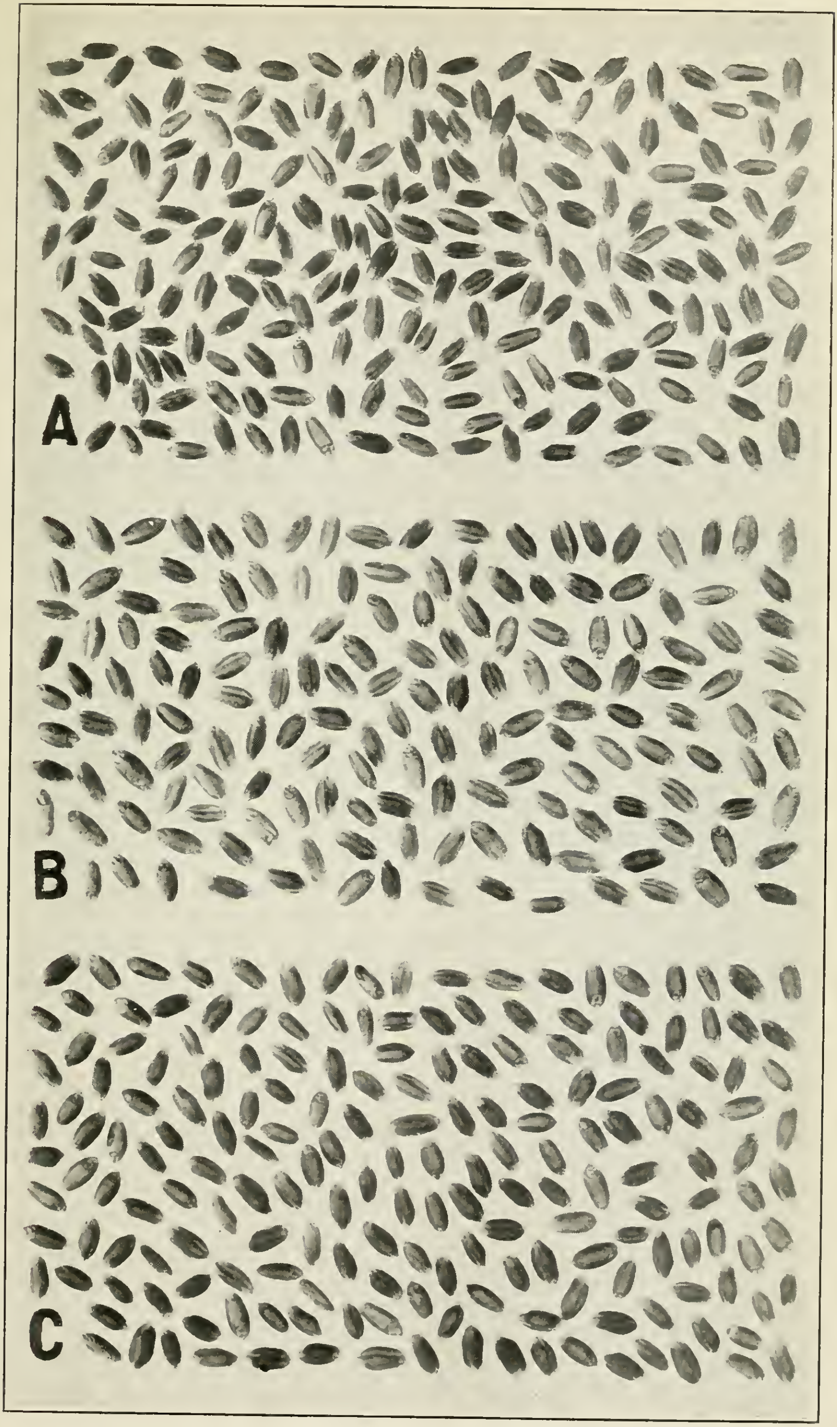
In shape of kernel and physical characters the Montana-grown Turkey wheat resembles that grown in Kansas, Nebraska, and other hard winter-wheat States, except in size of kernel. Usually the kernels are a little larger and quite often more plump. In this latter characteristic, however, there is as great a variation as in other sections. Plate I compares a typical sample of Montana-grown Turkey with two samples representing the usual variations of the Turkey wheat of the Central States.

The results of the milling, baking, and chemical studies with the samples of this variety or type are presented on the following pages in a series of tables and figures (Tables II and III and figures 3 to 13). Table II gives the results upon a limited number of samples of wheat of this type secured during the years 1908 and 1909, arranged according to the crop year, followed by a more comprehensive study that was made of the wheat of the three succeeding years.

It will be noted from this table that a very wide range in quality existed each year. The tests of the limited number of samples secured the first two years indicated that this wheat did not differ widely in quality from the hard winter wheats of other sections.

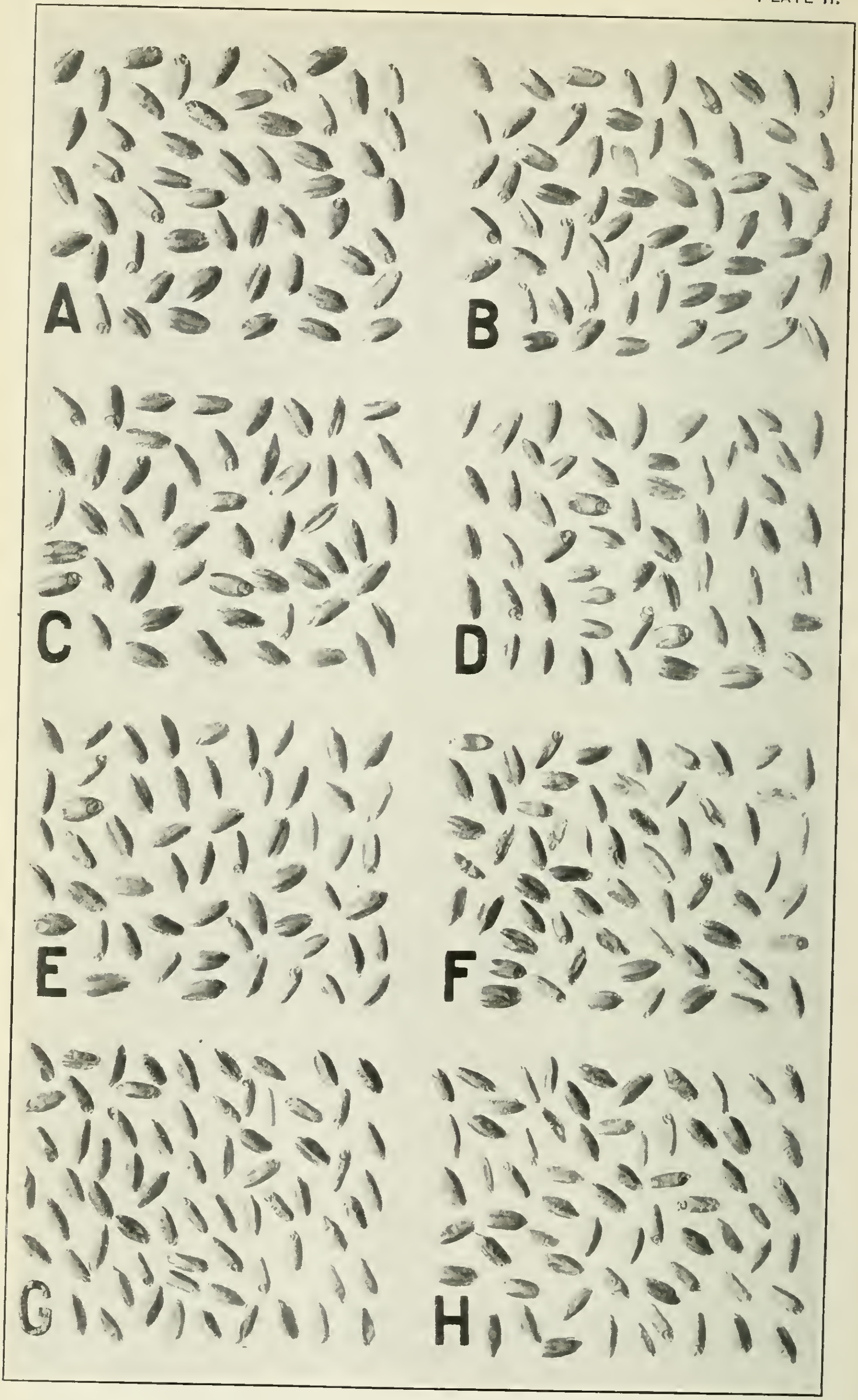
The tests for the three following years, 1910, 1911, and 1912, representing as they do a much larger number of samples, are far more interesting and suggestive. Certain striking variations were noted in the wheat of each crop year. That of 1910 was most uniform in quality. The samples secured were of about a uniform plumpness and were hard and glutinous. The results of the milling tests were likewise quite uniform. In absorption, the flour from the wheat of 1910 was lower than that of the two succeeding years; in the matter of strength, as indicated by loaf volume and texture, the flour was superior.

The wheat of the 1911 crop was not so uniform in quality as that of 1910. Many of the samples were more or less shrunken, and many were badly bleached and otherwise damaged in the field. Several samples, mostly from Fergus County, showed an abnormally high moisture content, due to rainy weather during harvest. These various factors are responsible for the much wider variation in milling results with the wheat of this year. Taken as a whole, the baking results with the flour did not differ greatly from the preceding year. The absorption was a little higher, and in strength there were no samples that ranked so high as those of the preceding year obtained from Yellowstone County. Two samples proved to be poorer than any that were obtained the previous year. The wheat of this year showed much greater range in crude protein. The variation, however, did not appear sectional and could probably be explained only by a study of local weather conditions.



COMPARISON OF MONTANA HARD WINTER (TURKEY) WHEAT WITH THAT OF OTHER SECTIONS, SHOWING THE LARGER AND MORE UNIFORM KERNELS OF THE MONTANA WHEAT.

A, Dark hard Turkey grown in Nebraska; *B*, typical Montana-grown Turkey; *C*, yellow-berry Turkey grown in Kansas.



ARRANGEMENT OF HARD WINTER WHEAT SAMPLES REFERRED TO IN TABLE III, CORRELATING PHYSICAL CHARACTERS AND MILLING QUALITY.

A and *B*, Plump or fairly plump, bright to slightly bleached; *C* and *D*, plump to a little shrunken, bleached, and a small percentage sprouted; *E* and *F*, plump to fairly thin, badly bleached, and a small percentage sprouted; *G* and *H*, badly bleached and sprouted or badly shrunken.

TABLE II.—*Baking tests of Montana hard winter (Turkey) wheat, showing sources of samples, milling quality, protein, and moisture content, for stated years.*

Sample No.	County in which grown.	Yield of straight flour.	Loss in milling.	Tests of straight flour.							Crude protein in wheat, N×5.7.	Moisture in wheat.
				Color of bread.	Absorption of water.	Strength.		Crude protein in flour, N×5.7.	Moisture in flour.			
						Volume of loaf.	Texture of flour.					
		P. ct.	*P. ct.*	*Score.*	*P. ct.*	*C. c.*	*Score.*	*P. ct.*	*P. ct.*		*P. ct.*	*P. ct.*
Crop of 1908:												
297 [a]	Cascade	71.6	4.4	98	58.8	2,270	......	12.54	8.85		12.94	12.0
Crop of 1909:												
507	....do	70.6	3.6	97	51.5	2,270	......	11.34	10.32		11.80	12.0
508	Gallatin	69.4	4.1	99	51.2	2,350	......	10.77	11.37		11.12	13.0
567 [b]	....	72.9	2.0	105	51.8	2,350	......	12.37	10.58		13.40	13.0
Crop of 1910:												
733	Cascade	72.6	.9	99	54.4	2,110	96	13.40	9.69		14.71	10.3
734	....do	72.0	.7	98	52.4	2,280	96	12.77	10.43		13.57	11.9
737	Fergus	73.0	1.3	97	56.5	2,250	98	12.37	9.61		13.74	10.2
738	....do	72.2	2.4	96	53.8	2,130	98	11.57	9.27		11.34	12.0
739	....do	72.8	.6	99	54.7	2,130	99	11.51	10.01		12.03	12.9
742	....do	74.2	0	98	54.1	1,950	98	11.17	9.45		12.08	9.8
743	....do	72.1	2.2	98	53.2	2,300	98	12.14	9.92		13.51	11.6
745	....do	71.9	[c].1	99	54.7	2,380	99	11.97	10.11		11.80	12.1
747	....do	72.8	.4	97	56.5	2,150	97	14.59	9.81		15.96	11.0
748	....do	72.3	.1	99	54.7	2,250	......	14.08	10.10		15.68	11.3
749	....do	74.4	.4	98	56.5	2,100	......	14.54	10.11		15.33	10.2
750	....do	70.8	1.7	96	56.2	2,150	......	14.54	10.84		15.16	12.0
756	....do	72.9	[c]2.7	96	54.1	2,220	94	14.08	......		15.68	12.8
726	Gallatin	73.4	0	99	52.6	1,900	96	9.41	9.86		10.26	10.8
730	....do	72.0	1.3	96	52.4	2,230	96	9.98	10.38		11.17	10.5
722	Yellowstone	67.7	3.8	97	53.8	2,520	100	12.65	10.87		12.71	12.3
723	....do	70.9	1.0	99	53.2	2,540	100	12.31	10.34		11.74	11.2
724	....do	70.5	1.2	98	52.9	2,350	100	12.26	10.02		12.94	11.2
Average (1910).	....	72.1	.84	98	54.3	2,225	98	12.56	10.06		13.26	11.4
Crop of 1911:												
1071	Flathead	69.2	4.1	96	55.3	2,190	95	9.41	10.25		10.20	13.6
947	Cascade	72.8	1.1	98	60.0	2,100	91	9.98	10.05		10.15	11.5
1075	....do	73.6	1.1	101	58.2	2,190	96	10.32	9.49		11.40	12.6
1076	....do	69.4	3.1	99	57.6	2,170	95	10.66	9.68		11.57	13.0
1050	Fergus	70.9	1.8	98	59.7	2,340	94	12.48	10.89		13.68	14.3
1051	....do	68.6	2.3	97	58.2	2,230	96	12.60	10.54		13.28	13.6
1052	....do	64.4	4.6	101	58.2	2,380	97	12.77	......		12.83	17.2
1053	....do	70.3	2.6	98	58.2	2,100	93	11.63	10.66		12.71	14.0
1054	....do	74.4	[c]1.4	100	58.5	2,080	96	13.85	9.87		14.82	11.9
1066	....do	66.9	1.1	94	56.8	2,190	90	13.57	10.13		15.05	13.4
1078	....do	68.3	1.1	95	55.0	2,100	96	13.22	10.43		15.28	13.4
1107	....do	71.1	2.1	94	61.5	2,230	92	12.31	10.18		12.60	12.5
1108	....do	69.0	2.8	101	59.7	2,250	94	11.63	10.73		12.31	13.6
1109	....do	70.2	4.7	98	61.8	2,000	92	9.12	10.29		9.18	14.2
1110	....do	71.9	1.6	98	58.8	2,070	94	11.69	10.47		11.51	14.6
1111	....do	70.2	4.0	103	61.5	2,130	94	10.03	10.55		10.37	14.4
1112	....do	70.1	2.2	103	59.1	2,210	95	10.83	10.93		11.97	15.4
1113	....do	71.2	.7	102	60.6	2,040	94	10.89	9.69		11.69	12.0
1114	....do	67.9	3.9	105	59.1	2,160	94	8.72	10.49		8.72	14.7
1115	....do	71.2	.4	99	58.8	2,150	95	10.83	10.07		12.37	13.0
1116	....do	71.2	2.3	99	61.2	2,270	95	10.83	10.61		11.17	14.0
1117	....do	66.5	1.4	94	60.2	2,370	95	12.03	9.72		13.05	12.0
1118	....do	73.4	[c]1.7	97	57.9	2,020	91	11.97	9.07		12.14	11.5
1119	....do	73.2	.7	100	58.5	2,130	94	9.86	9.50		10.20	11.4
1062	Lewis-Clark	78.2	1.6	101	57.9	2,190	96	8.61	9.67		8.32	11.8
1056	Ravalli	78.4	[c]3.1	100	57.6	2,080	96	9.86	9.30		10.37	10.2
1046	Gallatin	72.2	1.1	101	57.9	2,030	96	10.72	10.19		11.00	12.2
1048	....do	73.6	.2	98	57.9	1,890	94	9.23	9.95		9.92	11.1
1069	Park	74.6	1.6	94	58.2	1,880	92	9.12	10.01		9.12	13.9
1058	Meagher	72.1	1.8	98	58.5	2,040	93	10.77	10.13		11.74	14.0
1049	Custer	74.0	.3	98	56.5	2,140	94	10.83	9.41		11.17	11.2
Average (1911).	....	71.1	1.6	99	59.0	2,140	94	10.98	10.09		11.61	12.9

[a] Baking test with patent flour.
[b] Montana Turkey wheat secured at Chicago, Ill., where it was classed as Pacific coast red.
[c] Gain in milling.

TABLE II.—*Baking tests of Montana hard winter (Turkey) wheat, showing sources of samples, milling quality, protein, and moisture content for stated years*—Continued.

Sample No.	County in which grown.	Yield of straight flour.	Loss in milling.	Tests of straight flour.						Crude protein in wheat, N×5.7.	Moisture in wheat.
				Color of bread.	Absorption of water.	Strength.		Crude protein in flour, N×5.7.	Moisture in flour.		
						Volume of loaf.	Texture of flour.				
Crop of 1912:		*P. ct.*	*P. ct.*	*Score.*	*P. ct.*	*C. c.*	*Score.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1424	Chouteau	75.3	2.4	92	59.4	1,920	88	11.00	10.16	12.43	10.8
1421	Cascade	74.0	2.47	94	61.8	2,020	90	12.77	10.73	13.85	12.2
1423	do	68.4	3.55	92	59.7	1,960	98	10.83	10.89	12.08	12.5
1487	do	72.7	1.89	96	57.9	2,220	94	11.00	9.61	12.08	12.6
1490	do	72.5	1.62	92	61.2	1,885	92	10.20	10.46	10.72	12.0
1572	do	72.4	2.63	94	57.9	2,130	92	12.60	10.60	13.34	13.1
1425	Fergus	72.3	3.35	93	59.7	1,970	92	11.23	10.01	12.43	12.0
1426	do	70.8	3.55	90	55.9	2,020	92	12.20	10.95	13.00	13.0
1427	do	75.2	4.05	90	57.9	1,940	85	12.83	9.97	13.51	10.9
1430	do	75.6	1.23	90	57.4	1,940	88	12.83	10.45	12.94	11.2
1431	do	73.7	1.84	92	59.1	1,945	88	12.20	10.90	13.85	11.5
1482	do	68.3	4.97	94	58.5	2,080	94	10.03	11.19	10.77	12.4
1483	do	71.9	[a] 1.12	90	57.9	2,265	94	12.08	10.24	12.77	13.0
1484	do	74.7	[a] .11	93	50.6	2,000	94	10.55	10.45	11.17	13.3
1525	do	71.6	4.48	92	57.4	2,160	93	10.55	11.08	11.63	14.8
1526	do	72.4	2.12	92	57.9	2,050	90	11.34	10.92	12.48	12.4
1559	do	74.4	2.93	98	56.2	2,005	93	10.26	10.74	11.17	14.0
1455	Gallatin	76.6	.24	90	54.4	1,860	90	11.63	10.61	11.51	12.7
1456	do	74.7	.52	94	53.8	1,905	90	9.80	10.56	10.60	12.4
1459	do	76.8	[a] .14	94	53.5	1,825	90	10.09	11.45	10.83	12.6
1491	do	70.3	4.17	95	59.1	2,100	93	11.17	10.64	11.80	12.8
1462	Yellowstone	72.4	4.59	95	58.8	1,940	94	11.49	9.81	11.97	12.6
1485	do	68.3	4.65	95	57.9	2,110	92	12.77	10.48	13.57	12.2
1486	do	64.7	3.73	95	54.1	1,925	92	8.95	10.46	9.06	13.7
1454	Rosebud	74.5	1.54	95	53.8	2,220	95	12.14	11.29	13.74	13.0
1458	do	72.3	1.21	96	56.2	2,230	90	11.40	11.38	13.05	14.1
Average (1912).		72.5	2.40	93.2	57.2	2,063	91	11.30	10.62	12.16	12.6
Crop of 1912: [b]											
1974	Fergus	70.8	4.6	97	60.6	2,120	92	10.72	11.71	11.57	13.0
1975	do	72.7	1.8	94	60.6	2,280	91	12.77	11.38	14.54	13.1
Crop of 1913:											
1973	do	72.4	2.7	96	61.8	2,070	92.5	11.97	11.55	13.40	12.5

[a] Gain in milling. [b] Tested in 1913.

Typical loaves from the flour of the 1912 wheat crop are shown in figure 3. The Montana wheat of the 1912 crop showed certain characteristics that were peculiar to most of the northern-grown wheats

FIG. 3.—Loaves of bread from Turkey wheat grown in Cascade and Fergus Counties, Mont., crop of 1912: *a*, From Cascade County; *b*, *c*, *d*, *e*, and *f*, from Fergus County.

that year. The wheat was quite uniformly plump and gave a good yield of flour, which, however, was not of the best color, being for the most part quite creamy. Likewise, the wheat of this year was not of high baking strength, though containing a fair amount of gluten. In strength, as indicated by loaf volume and texture, this wheat was decidedly the poorest of the three years. This characteristic was apparently due to certain climatic conditions that were general throughout the 1912 wheat-growing season, as the same variations were noted with Montana spring wheat and the spring wheat of Minnesota and the Dakotas. This is shown diagrammatically in figure 4, which compares the loaf volume and texture of loaves made from flour representing wheats of the crops of 1911 and 1912. The results for northern spring wheat are based upon the average of tests with composite samples of spring wheat secured at Minneapolis and Chicago. Figure 5 is a diagrammatic presentation of the results of the milling and baking tests of the samples of the three years 1910, 1911, and 1912 and summarizes the results presented in Table II for those years.

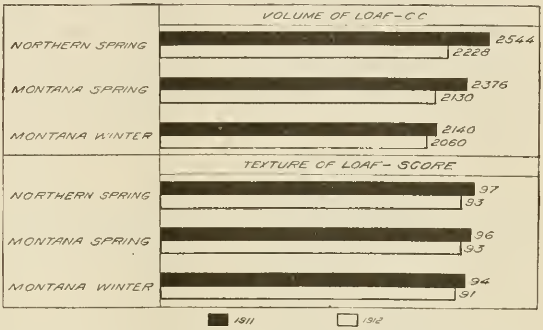


FIG. 4.—Diagram comparing northern-grown wheat of the 1911 and 1912 crops, showing the generally lower strength of the wheat crop of 1912.

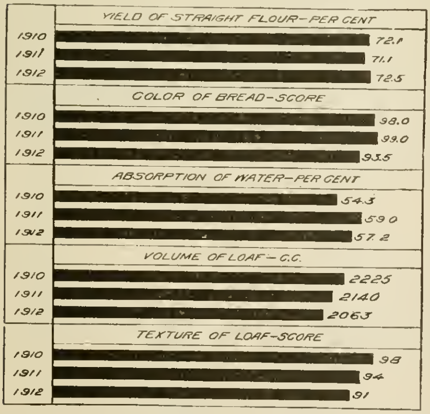


FIG. 5.—Diagram comparing the crops of 1910, 1911, and 1912 of Montana Turkey wheat.

CORRELATION OF PHYSICAL CHARACTERS AND MILLING QUALITY.

In order to determine how far the physical characteristics and condition of these samples could be correlated with actual quality, as evidenced by the milling and baking tests, several groupings were arranged in Table III. The arrangement of the samples in these tables was based upon notes taken after careful examination of the external appearance of each sample and then dividing them into several groups, as follows:

(1) Montana hard winter (Turkey) wheat, plump or fairly plump and bright to slightly bleached. Samples answering to this description were arranged in group A of Table III.

(2) Montana hard winter (Turkey) wheat, plump to a little shrunken, bleached, and a small percentage sprouted (Table III, group B).

(3) Montana hard winter (Turkey) wheat, plump to fairly thin, badly bleached, and a small percentage sprouted (Table III, group C).

(4) Montana hard winter (Turkey) wheat, badly bleached, and sprouted or badly shrunken (Table III, group D).

An attempt is made in Plate II to illustrate these groupings by reproducing photographs of typical samples from each group.

Each of the samples was also submitted to two or more persons acquainted with commercial practices, who were asked to give their opinions as to the proper grading and classification of the samples. This grading and also notes on "Condition" appear in the table.

A study of Table III reveals a number of interesting facts. As might be expected, the plump and sound samples falling in group A were of a uniformly high weight per bushel, a marked decrease occurring between each group. The grading followed this arrangement only roughly. In group A none of the samples were graded lower than No. 2 hard winter, though in one instance sample No. 1049 was graded No. 1 western red. In the succeeding groups there is considerable disagreement in the grading but not in the classification.

That the samples which are plump and sound are of highest quality from the standpoint of milling yield is clearly shown by a comparison of these groups. The average percentage of flour obtained from the samples falling in group A was 73.2 per cent, and in the three groups following, 71.7, 70.7, and 67.2 per cent, respectively. In the matter of flour quality, and especially in the factor of strength, however, the reverse is true, there being a marked increase in volume of loaf where there was a decrease in flour yield. This is in confirmation of the general observation that high baking strength is not generally found in wheat of extreme plumpness.

Table III.—*Correlation of physical characters and milling quality of Montana hard winter (Turkey) wheat for stated years.*

Group A.—Grain Plump or Fairly Plump, Bright to Slightly Bleached, and Otherwise Sound.

Sample No.	Weight per bushel, cleaned.	Moisture in wheat.	Condition.	Commercial classification and grade. Inspector A.	Inspector B.	Inspector C.	Yield of straight flour.	Tests of straight flour. Color of bread.	Absorption of water.	Strength. Volume of loaf.	Texture of loaf.
Crop of 1910:	*Pounds.*	*Per ct.*					*Per ct.*	*Score.*	*Per ct.*	*C. c.*	*Score.*
723	62	11.2		No. 1 hard winter		No. 1 hard winter	70.9	99	53.2	2,540	100
726	65	10.8	Sound, fairly plump	do		do	73.4	99	52.6	1,900	96
730	65	10.5	Sound, plump	do		do	72.0	96	52.4	2,230	96
733	64	10.3	Sound, fairly plump	do		do	72.6	99	54.4	2,110	96
737	64.5	10.2	do			do	73.0	97	56.5	2,250	98
738	66	12.0	do			do	72.2	96	53.8	2,130	98
739	65.5	12.9	do			do	72.8	99	54.7	2,130	99
742	66	9.8	do			do	74.2	98	54.1	1,950	98
745	63	12.1	Slightly bleached, plump	No. 1 hard winter		do	71.9	99	54.7	2,380	99
747	63.5	11.0	Sound, fairly plump	do		do	72.8	97	56.5	2,150	97
749	63	10.2	do	do		do	74.4	98	56.5	2,100	......
Average (1910)	64.3	11.0					72.8	98	54.5	2,170	98
Crop of 1911:											
947	62	11.5	Sound, plump	do	No. 1 hard winter	do	72.8	98	60.0	2,100	94
1048	61	11.1	Sound, fairly plump	do	do	do	73.6	98	57.9	1,890	94
1049	61	11.2	do	do	No. 1 western red	No. 2 hard winter	74.0	98	56.5	2,140	94
1053	61	14.0	Sound, plump	do	No. 1 hard winter	No. 1 hard winter	70.3	98	58.2	2,100	93
1054	61	11.9	do	do	do	do	74.4	100	58.5	2,080	96
1058	60	14.0	Sound, fairly plump	do	No. 2 hard winter	No. 2 hard winter	72.1	98	58.5	2,040	93
1069	64	13.9	Sound, plump	do	No. 1 hard winter	No. 1 hard winter	74.6	94	58.2	1,880	92
1075	61.5	12.6	do	do	No. 2 hard winter	do	73.6	101	58.2	2,190	96
1110	61	14.6	do	do	do	No. 2 hard winter	71.9	98	58.8	2,070	94
1113	62	12.0	do	do	No. 1 hard winter	No. 1 hard winter	74.2	102	60.6	2,040	94
1118	61	11.5	do	do	No. 2 hard winter	do	73.4	97	57.9	2,020	94
Average (1911)	61.4	12.6					73.2	98	58.5	2,050	94
Crop of 1912:											
1421	61.5	12.2	Slightly bleached, fairly plump	do		No. 1 hard winter	74.0	94	61.8	2,020	90
1424	60	10.8	Sound, plump	do		do	75.3	92	59.4	1,920	88
1427	61	10.9	do	do		do	75.2	90	57.9	1,940	85

TABLE III.—*Correlation of physical characters and milling quality of Montana hard winter (Turkey) wheat for stated years*—Continued.

GROUP A.—GRAIN PLUMP OR FAIRLY PLUMP, BRIGHT OR SLIGHTLY BLEACHED, AND OTHERWISE SOUND—Continued.

Sample No.	Weight per bushel, cleaned.	Moisture in wheat.	Condition.	Commercial classification and grade.			Yield of straight flour.	Tests of straight flour.			
				Inspector A.	Inspector B.	Inspector C.		Color of bread.	Absorption of water.	Strength.	
										Volume of loaf.	Texture of loaf.
Crop of 1912—Contd.	*Pounds.*	*Per ct.*					*Per ct.*	*Score.*	*Per ct.*	*C. c.*	*Score.*
1430	62	11.2	Slightly bleached, fairly plump	No. 1 hard winter.		No. 1 hard winter.	75.6	90	57.4	1,940	88
1455	62.5	12.7	Slightly bleached, plump	do		do	76.6	90	54.4	1,860	90
1482	63	12.4	do	do		do	68.3	94	58.5	2,080	94
1490	65	12.0	Sound, plump	do		do	72.5	92	61.2	1,885	92
1526	64	12.4	Slightly bleached, plump	do		do	72.4	92	57.9	2,050	90
1559	61	14.0	Sound, plump	do		do	74.4	98	56.2	2,005	93
1572	62	13.1	Sound, shrunken	No. 2 hard winter.		No. 2 hard winter.	72.4	94	57.9	2,130	92
Average (1912)	62.2	12.2					73.7	93	58.3	1,983	90
3-year average	62.7	11.6					73.2	97	57.0	2,020	94

GROUP B.—GRAIN PLUMP TO A LITTLE SHRUNKEN, BLEACHED, AND A SMALL PERCENTAGE SPROUTED.

Sample No.	Weight per bushel, cleaned.	Moisture in wheat.	Condition.	Inspector A.	Inspector B.	Inspector C.	Yield of straight flour.	Color of bread.	Absorption of water.	Volume of loaf.	Texture of loaf.
Crop of 1910:											
724	60	11.3	Bleached, shrunken	No. 2 hard winter.		No. 2 hard winter.	70.5	98	52.9	2,350	100
743	63	11.6	Bleached, sprouted, plump			do	72.1	98	53.2	2,300	98
748	61	11.3	Bleached, shrunken, sprouted	No. 2 hard winter.		do	72.3	99	54.7	2,250	......
750	61.5	12.0	do	do		do	70.8	96	56.2	2,150	......
756	62	12.8	Bleached, plump	do		do	72.9	96	54.1	2,220	94
Average (1910)	61.5	11.8					71.7	97	54.2	2,254	97
Crop of 1911:											
1046	60.5	12.2	Bleached, 2 per cent sprouted, plump.	No. 1 hard winter.	No. 3 hard winter.	do	72.2	101	57.9	2,030	96
1056	64	10.2	Bleached, sprouted, plump	do	do	No. 3 hard winter.	78.4	100	57.6	2,080	96
1062	61	11.8	Bleached, plump	No. 2 hard winter.	do	No. 2 hard winter.	72.2	101	57.9	2,190	96
1071	61	13.6	Bleached, 5 per cent sprouted, plump.	No. 1 hard winter.	do	do	69.2	96	55.3	2,190	95
1076	60	13.0	Bleached, plump	No. 2 hard winter.	do	do	69.4	99	57.6	2,170	95
1109	60	14.2	do	No. 1 hard winter.	No. 2 hard winter.	do	70.2	98	61.8	2,000	92

1114	61	14.7	....do	No. 3 hard winter	No. 3 hard winter		67.9	105	59.1	2,160	94
1115	60	13.0	Bleached, fairly plump	No. 2 hard winter	No. 2 hard winter	No. 2 hard winter	71.2	99	58.8	2,150	95
1119	59	11.4	Bleached, shrunken	....do	....do	....do	73.2	100	58.5	2,130	94
Average (1911)	60.7	12.7					71.5	100	58.3	2,122	95
Crop of 1912:											
1426	60	13.0	Bleached, sprouted, plump	No. 1 hard winter		No. 3 hard winter	70.8	90	55.9	2,020	92
1456	61	12.4	Bleached, plump	....do		No. 2 hard winter	74.7	94	53.8	1,905	90
1459	62	12.6	....do	No. 2 hard winter		....do	76.8	94	53.5	1,825	90
1462	60	12.6	....do			....do	72.4	95	58.8	1,940	94
1474	63	13.3	Bleached, sprouted, plump	No. 2 hard winter		....do	74.7	93	50.6	2,000	94
1485	62	12.2	Slightly bleached, shrunken	....do		....do	68.3	95	57.9	2,110	92
1486	62	13.7	Bleached, shrunken	....do		....do	64.7	95	54.1	1,925	92
1487	64	12.6	Bleached, plump	....do		....do	72.7	96	57.9	2,220	94
1525	62.5	14.8	Bleached, sprouted, plump	No. 1 hard winter		....do	71.6	92	57.4	2,160	93
Average (1912)	61.8	12.9					71.7	94	55.5	2,012	92
3-year average	61.3	12.1					71.7	97	56.3	2,108	94

GROUP C.—GRAIN PLUMP TO FAIRLY THIN, BADLY BLEACHED, AND A SMALL PERCENTAGE SPROUTED.

Crop of 1910:											
734	62	11.9	Badly bleached, sprouted, plump	No. 2 hard winter		No. 2 hard winter	72.0	98	52.4	2,380	96
Crop of 1911:											
1050	59	14.3	Badly bleached, 8 per cent sprouted, plump.	....do	No. 3 hard winter	No. 3 hard winter	70.9	98	59.7	2,340	94
1051	58	13.6	Badly bleached, 9 per cent sprouted, fairly plump.	No. 3 hard winter	....do	....do	68.6	97	58.2	2,230	96
1052	59	17.2	Badly bleached, 8 per cent sprouted, plump.	No. 2 hard winter	....do	....do	64.4	101	58.2	2,380	97
1108	60	13.6	Badly bleached, plump	No. 3 hard winter	....do	....do	69.0	101	59.7	2,250	94
1111	61	14.4	....do	No. 2 hard winter	....do	....do	70.2	103	61.5	2,130	94
1116	61	14.0	....do	....do	....do	....do	71.2	99	61.2	2,270	95
Average (1911)	59.7	14.5					69.1	100	59.8	2,267	95
Crop of 1912:											
1423	57.5	12.5	Bleached, shrunken	No. 1 hard winter		No. 3 hard winter	68.4	92	59.7	1,960	88
1425	58	12.0	Badly bleached, sprouted, plump	....do		....do	72.3	93	59.7	1,970	92
1431	57	11.5	....do	....do		....do	73.7	92	59.1	1,945	88
1454	60	13.0	....do	No. 2 hard winter		No. 2 hard winter	74.5	95	53.8	2,220	95
1458	59	14.1	....do	....do		No. 3 hard winter	72.3	96	56.2	2,230	90
1483	61	13.1	Badly bleached, shrunken	....do		No. 2 hard winter	71.9	90	57.9	2,265	94
1491	62	12.8	Badly bleached, sprouted, plump	....do		....do	70.3	95	59.1	2,100	93
Average (1912)	59.2	12.7					71.9	93	57.9	2,099	91
3-year average	59.6	13.4					70.7	96	58.3	2,191	93

TABLE III.—*Correlation of physical characters and milling quality of Montana hard winter (Turkey) wheat for stated years*—Continued.

GROUP D.—GRAIN BADLY SPROUTED OR BADLY SHRUNKEN.

Sample No.	Weight per bushel, cleaned.	Moisture in wheat.	Condition.	Commercial classification and grade.			Yield of straight flour.	Tests of straight flour.			
				Inspector A.	Inspector B.	Inspector C.		Color of bread.	Absorption of water.	Strength.	
										Volume of loaf.	Texture of loaf.
Crop of 1911:	*Pounds.*	*Per ct.*					*Per ct.*	*Score.*	*Per ct.*	*C.c.*	*Score.*
1066	55	13.4	Shrunken, 30 per cent sprouted	No. 3 hard winter.	No. 4 western red.	No. 4 hard winter.	66.9	94	56.8	2,190	90
1078	56	13.4	Shrunken, 6 per cent sprouted	No. 4 hard winter.	do	do	68.3	95	55.0	2,100	96
1117	58	12.0	Shrunken	No. 3 hard winter.	No. 3 hard winter.	No. 3 hard winter.	66.5	94	60.2	2,370	95
Average (1911)	56.3	12.9					67.2	94.3	57.3	2,220	93.6

COMPARISONS WITH THE HARD WINTER WHEATS OF OTHER SECTIONS.

How does the quality of Montana-grown hard winter wheat compare with that grown in other sections? Outwardly the kernels appear to be a little larger, more uniform, and somewhat more plump on the average. The kernels are very hard and vary in color from dark amber to reddish. The "yellow berry," so prevalent in some sections, is not common in Montana, although it has occasionally been observed. That there is almost as great a variation in the characteristics and quality of the wheat of this State as in all other sections of the United States where hard winter wheat is grown is shown in figures 6 to 13.

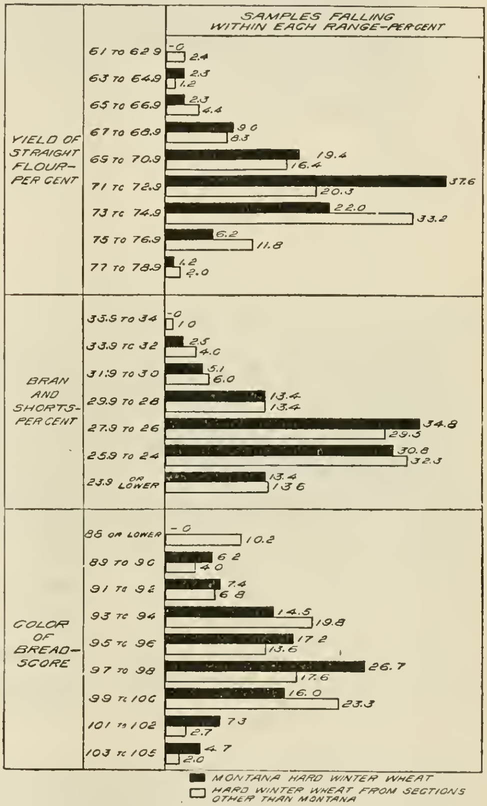


FIG. 6.—Diagram comparing the milling quality (yield of straight flour, bran, and shorts, and color of flour) of Montana hard winter wheat with that of the hard winter wheat of other sections. The results of tests of samples of the crops of 1908 to 1913, inclusive, are shown.

In milling quality, restricting the meaning of this term to flour yield, the Montana-grown wheat resembles the hard winter wheats of the central Plains area very closely. This is evidenced by a comparison of the data shown diagrammatically in figures 6, 7, and 8. The flour yield does not appear to average quite as high in the comparisons made in figure 6, but this is readily explained by the fact that on the average the Montana samples were considerably higher in moisture content, a factor which very materially influences the flour yield, as is clearly illustrated in figure 7. In flour color the Montana wheat shows up to advantage, as none of the samples tested were seriously injured by the presence of smut or from field damage, as was the case with a number of samples from other sections.

Figure 8 shows that in weight per measured bushel the Montana wheat has about the same range as that observed in the wheat from other hard winter-wheat sections, a very large percentage of the samples falling between 60 and 64 pounds in both instances. The general relationship between weight per bushel and flour yield is also illustrated in this diagram. With increase in weight per bushel it will be noted that there is also an increase in the average flour yield.

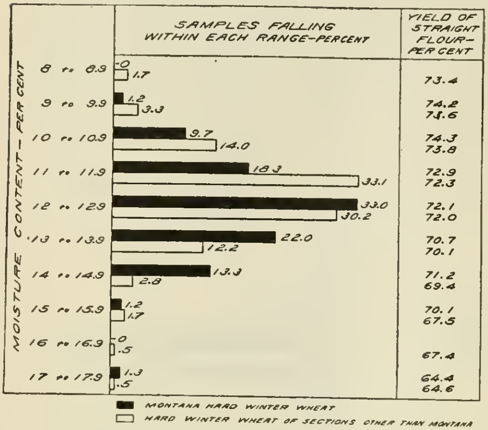


FIG. 7.—Diagram comparing the moisture content of Montana hard winter wheat with the hard winter wheat of other sections and showing the relationship of this factor to the average flour yield.

As is illustrated in figure 9, the baking strength of Montana hard winter-wheat flour is lower on the average than that of other sections, when the factors of loaf volume and texture are considered. This difference is undoubtedly emphasized by the unusually low strength of the Montana wheat in 1912, but, on the other hand, very few of the Montana samples showed the very high strength of the "shoepeg" or dark Turkey wheat of central and western Kansas. Figure 10 illustrates this point. The loaf marked *a* is made from a hard dark Turkey wheat from Kansas and is decidedly superior in strength to any of the other samples shown. On

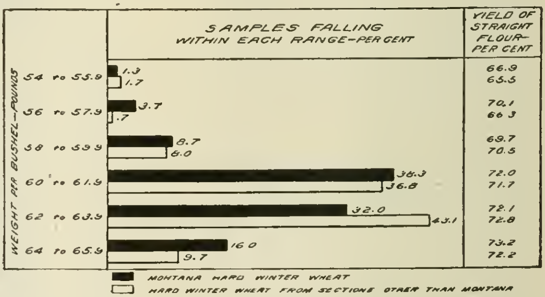


FIG. 8.—Diagram comparing the weight per bushel of Montana hard winter wheat with that of the hard winter wheat of other sections, showing the relationship of this factor to the average flour yield.

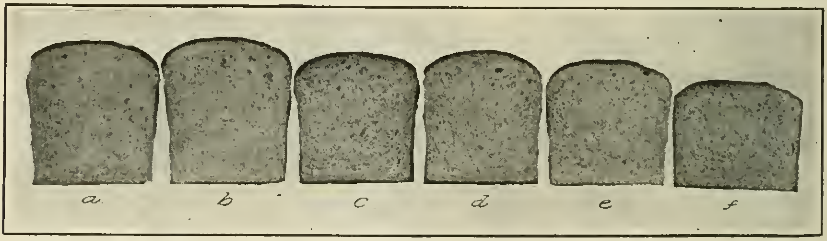


FIG. 9.—Comparison of loaves from Montana-grown wheat with a composite sample of No. 2 hard winter wheat from Chicago, Ill., crop of 1912: *a*, Chicago No. 2 hard winter; *b*, Turkey, from Rosebud County, Mont.; *c*, *d*, and *e*, Turkey, from Gallatin County, Mont.; *f*, Spring Club (western white), from Gallatin County.

the other hand, the loaf marked *b* represents "yellow" Turkey

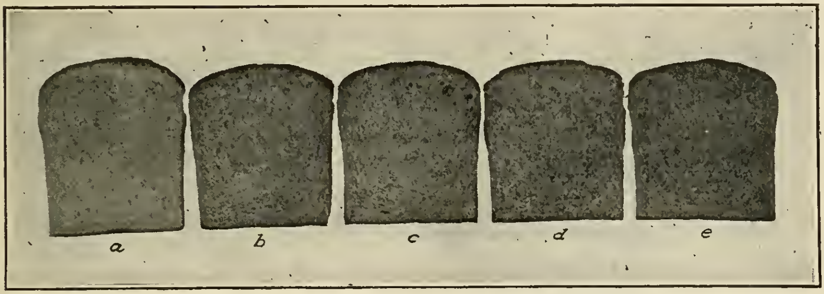


Fig. 10.—Comparison of loaves from No. 2 hard winter wheat obtained at Kansas City, Mo., with samples of Montana Turkey wheat, crop of 1911: *a*, No. 2 hard winter (dark), Kansas City; *b*, No. 2 hard winter (yellow), Kansas City; *c*, *d*, and *e*, Montana-grown Turkey. Part of the apparent difference in color is due to unequal lighting. Notice the similarity of *b* to *c*, *d*, and *e* and the superiority of *a* in baking strength.

wheat from Kansas and resembles very closely loaves *c*, *d*, and *e*, which are from Montana Turkey wheat. The conclusion that may be drawn from this illustration is that although Montana wheat does not often exhibit exceptionally high strength, yet practically all samples fall within the general range in quality found in the hard winter wheat of other sections. That this condition might be reversed in

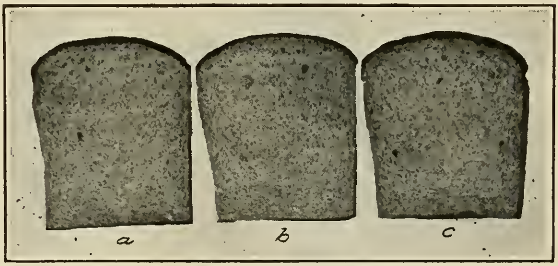


Fig. 11.—Cross section of loaves baked from the flour of Montana-grown hard winter wheat and St. Louis No. 2 hard winter: *a*, St. Louis No. 2 hard winter; *b*, No. 2 hard winter wheat, from the port of New York, said to be Montana wheat; *c*, Turkey, from Fergus County, Mont. All loaves are similar; *a*, however, has the best texture.

Fig. 12.—Comparison of bread from Montana wheat with a sample of No. 2 hard winter from Chicago: *a*, Chicago No. 2 hard winter; *b*, Turkey, from Yellowstone County; *c*, *d*, and *e*, Turkey, from Gallatin County; *f*, Spring Club (white), from Gallatin County.

some seasons is within the range of possibility. The point is that local climatic and other environmental factors have great influence on the quality of the wheat and these factors may vary greatly from year to year. The usual differences that are found in bread made from hard winter-wheat flour are well illustrated in figures 11 and 12, and it will be noted that as a rule the loaves from the Montana wheat do not suffer by comparison.

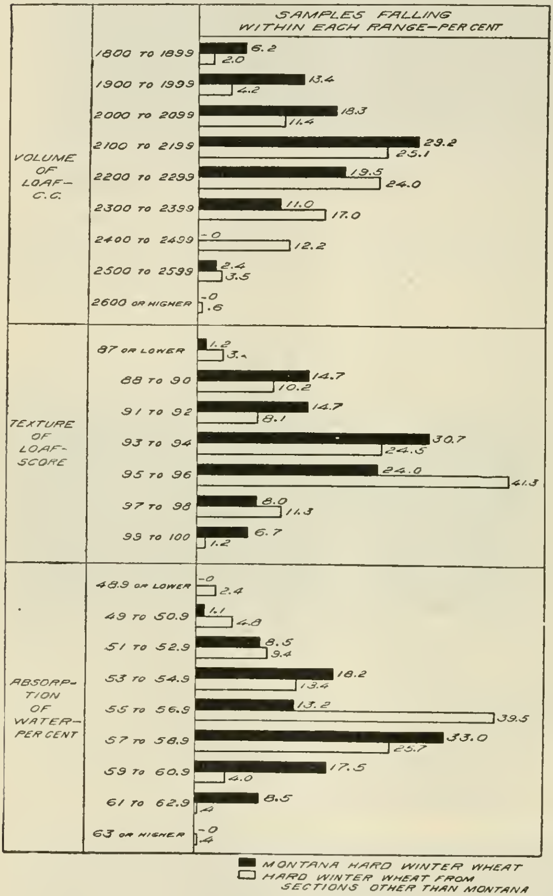


FIG. 13.—Diagram comparing the strength (loaf volume, texture, and water absorption) of the flour from Montana hard winter wheat with that from hard winter wheat of other sections. The results of tests of samples of the crops of 1908 to 1913, inclusive, are shown.

One factor which has not yet been mentioned is water absorption of the flour. The comparisons made diagrammatically in figure 13 show that the Montana wheat flour shows up rather more favorably than the general run of flour from hard winter wheat of other sections.

To summarize these comparisons between Montana hard winter wheat and that of other sections, it may be said that, eliminating the differences brought about by high moisture content, the Montana wheat, which is plump and sound and of high weight per bushel, gives about the same flour yield as similar hard winter wheat from other sections and that the color of the flour is likewise equal, if not better. In baking quality few, if any, of the Montana samples showed exceptionally high strength, but all of them fell within the range of quality found in the hard winter wheat of other sections, although with a lower general average. The flour from the Montana wheat averages considerably higher in water absorption.

MONTANA HARD SPRING WHEAT.

Montana-grown spring wheat of the common varieties of the Fife and Bluestem groups when received at primary markets is as a rule classified and graded on the same basis as the hard spring wheat grown in the Dakotas and Minnesota; that is, as northern spring wheat. Spring wheat, like the winter wheat grown within the State of Montana, has a somewhat larger and plumper kernel, but in milling quality and general characteristics it does not seem to differ materially from the general run of the spring wheat of the Dakotas and Minnesota, except that the tendency toward lower baking strength as a corollary to the plumper kernels seems to exist here also.

The same variations in baking strength of the crops of 1910, 1911, and 1912 are apparent with the spring wheats as were observed with the winter wheats. Drawing conclusions from Tables IV, V, and VI, it appears that the spring wheat of the crops of 1908 to 1910, inclusive, was of a quality much superior to that of the two succeeding years, and that the wheat of the 1912 crop, like that of the northern-grown wheat, was generally low in strength, as shown in figure 4. Complete information in regard to the spring-wheat samples is to be found in Tables IV and V.

Table V shows some of the characteristics and quality of each sample and the relationship of these factors to their commercial rating and milling quality. It will be noted that the dry, sound, and plump samples are usually high in milling quality, though no very great range is observed. The classification and grading of these samples were quite uniform. The grade appraised is more nearly dependent upon the external appearance of the samples than upon other factors as would be expected, bleached, sprouted, and "frosted" samples being the only ones grading lower than No. 1 northern. The tendency of throwing into the western red class samples which are not up to the standard is noted in connection with sample No. 1057.

TABLE IV.—*Baking tests of Montana spring wheat, showing sources of samples, variety, and milling quality for five successive years.*

Sample No.	County in which grown.	Variety.	Yields of straight flour.	Loss in milling.	Tests of straight flour. Color of bread.	Tests of straight flour. Absorption of water.	Tests of straight flour. Strength. Volume of loaf.	Tests of straight flour. Strength. Texture of loaf.	Tests of straight flour. Crude protein in flour, N×5.7.	Tests of straight flour. Moisture in flour.	Crude protein in wheat, N×5.7.	Moisture in wheat.
			Per cent.	*Per cent.*	*Score.*	*Per cent.*	*C. c.*	*Score.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Crop of 1908:												
298 [a]	Cascade	Mixed [b]	71.5	0.72	100	56.2	2,490	......	12.77	8.49	13.74	11.9
358 [a]	Fergus	65 per cent Fife.	73.2	[c] 1.68	102	56.5	2,305	......	12.89	......	13.34	11.2
Crop of 1909:												
506	Cascade		72.1	[c] .2	100	51.8	2,450	......	11.51	11.34	11.63	13.4
509	Gallatin		63.4	2.0	103	51.5	2,530	......	10.60	11.44	11.17	13.8
Crop of 1910:												
735	Cascade	Mixed [b]	70.2	.6	102	54.4	2,640	100	11.46	10.39	11.17	12.3
736	do	do [b]	71.4	2.4	99	53.2	2,600	98	13.34	10.26	14.59	11.7
740	Fergus	Fife	72.5	1.5	99	54.7	2,420	98	13.11	10.09	13.91	11.9
741	do	do	68.2	3.5	96	52.9	2,580	100	13.62	10.07	13.51	11.8
744	do	do	71.0	.3	100	51.8	2,400	100	11.97	10.82	12.48	13.2
727	Gallatin	do	70.2	3.1	101	52.9	2,580	100	11.86	10.85	13.05	12.3
731	do	do	73.4	2.1	96	52.4	2,310	96	10.37	11.10	10.49	14.2
725	Yellowstone	do [b]	72.4	1.7	102	53.2	2,500	100	12.71	10.17	13.74	11.6
Average (1910).			71.2	1.9	99	53.9	2,504	99	12.31	10.47	12.87	12.4
Crop of 1911:												
948	Cascade	Fife	69.4	1.8	103	58.8	2,515	98	10.37	10.86	11.12	14.0
1073	do	Mixed [b]	72.5	.3	99	57.1	2,350	96	12.31	11.01	14.14	14.6
1074	do	do. [b]	69.8	3.4	100	58.5	2,570	100	12.25	10.90	12.37	14.9
1070	Flathead	Fife	70.2	2.2	98	61.8	2,300	95	11.34	9.99	11.57	13.6
1059	Meagher	do	74.6	2.2	97	59.4	2,190	93	11.97	9.40	12.14	13.6
1057	Ravalli	do	70.1	3.2	97	57.4	2,330	95	10.55	10.98	10.83	15.4
Average (1911).			71.1	2.2	99	58.8	2,376	96	11.46	10.52	12.03	14.4
Crop of 1912:												
1470	Valley	Bluestem	70.2	4.1	94	58.2	2,080	94	10.89	10.70	11.63	14.2
1429	Chouteau	Fife	70.4	4.0	93	58.5	2,090	90	12.20	10.29	12.54	13.6
1422	Cascade	do	70.7	4.0	95	59.1	2,295	94	13.45	......	14.19	12.3
1488	do	Mixed [b]	70.9	4.3	94	58.3	2,110	92	12.14	9.67	12.60	12.4
1489	do	do. [b]	71.5	3.4	96	60.0	2,085	93	11.63	10.34	11.63	14.1
1533	do	do. [b]	73.5	.6	98	56.8	2,210	95	11.40	9.61	11.57	12.0
1428	Fergus	Bluestem	71.7	3.4	95	58.5	2,055	90	12.48	10.56	12.37	11.8
1457	Gallatin	Fife	75.2	1.4	92	56.2	2,060	94	11.97	11.33	12.60	14.8
1461	do	do	69.4	4.7	93	59.7	2,180	94	12.31	11.21	12.43	13.0
Average (1912).			71.5	3.3	94	58.4	2,129	93	12.05	10.46	12.40	13.1
5-year average.			71.1	2.3	98	56.4	2,342	96	11.98	10.47	12.47	13.1

[a] Baking test upon approximately a 70 per cent patent flour.
[b] Largely Fife and Bluestem.
[c] Gain in milling.

Table V.—*Correlation of physical characters and milling quality of Montana hard spring wheat, showing condition, commercial grading, and milling and baking quality of samples for three successive years.*

Sample No.	Weight per bushel, cleaned.	Moisture in wheat.	Condition.	Commercial classification and grade.			Yield of straight flour.	Tests of straight flour.			
				Inspector A.	Inspector B.	Inspector C.		Color of bread.	Absorption of water.	Strength.	
										Volume of loaf.	Texture of loaf.
Crop of 1910:	*Lbs.*	*Per ct.*					*Per ct.*	*Score.*	*Per ct.*	*C. c.*	*Score.*
725	62	11.6	Bleached, plump	No. 1 northern		No. 1 northern	72.4	102	53.2	2,500	100
727	61	12.3	Bleached, 10 per cent white, plump	do		No. 2 northern	70.2	101	52.9	2,580	100
731	65	14.2	Sound, plump	do		No. 1 hard spring	73.4	96	52.4	2,310	96
735	61	12.3	Sound, fairly plump	do		No. 1 northern	70.2	102	54.4	2,640	100
736	60	11.7	Bleached, shrunken	No. 2 northern		do	71.4	99	53.2	2,600	98
740	62	11.9	Sound, fairly plump			do	72.5	99	54.7	2,420	98
741	61	11.8	do			do	68.2	96	52.9	2,580	100
744	63.5	13.2	Sound, plump	No. 1 northern		No. 1 hard spring	71.0	100	51.8	2,400	100
Average (1910)	61.9	12.4					71.2	99	53.9	2,504	99
Crop of 1911:											
948	62	14.0	Sound, plump	No. 1 northern	No. 2 northern	No. 1 northern	69.4	103	58.8	2,515	98
1057	60.5	15.4	Bleached, "frosted"	do	No. 4 western red	No. 3 northern	70.1	97	57.4	2,330	95
1059	61	13.6	Sound, plump	do	No. 1 northern	No. 1 northern	74.6	97	59.4	2,190	93
1070	61	13.6	Sound, fairly plump	do	No. 1 hard spring	do	70.2	98	61.8	2,300	95
1073	61	14.6	Bleached, plump	do	No. 1 northern	do	72.5	99	57.1	2,350	96
1074	59	14.9	do	No. 2 northern	No. 3 northern	No. 2 northern	69.8	100	58.5	2,570	98
Average (1911)	60.8	14.4					71.1	99	58.8	2,376	96
Crop of 1912:											
1422	58	12.3	Slightly bleached, shrunken	No. 1 northern		No. 1 northern	70.7	95	59.1	2,295	94
1428	61	11.8	Slightly bleached, fairly plump	do		do	71.1	95	58.5	2,055	90
1429	57	13.6	Sound, shrunken	do		do	70.4	93	58.5	2,090	90
1457	60.5	14.8	Sound, plump	No. 1 hard spring		No. 1 hard spring	75.2	92	56.2	2,060	94
1461	58	13.0	Bleached, plump, "frosted"	No. 2 northern		No. 3 northern	69.4	93	59.7	2,180	94
1470	59	14.2	Bleached, shrunken			No. 2 northern	70.2	94	58.2	2,080	94
1488	62	12.4	Slightly bleached, fairly plump	No. 1 northern		No. 1 northern	70.9	94	58.3	2,110	92
1489	60.5	14.1	Bleached, sprouted, fairly plump	No. 2 northern		No. 2 northern	71.5	96	60.0	2,085	93
1533	61	12.0	Slightly bleached, plump	No. 1 hard spring		No. 1 hard spring	73.5	98	56.8	2,210	95
Average (1912)	59.7	13.1					71.5	94	58.4	2,129	93
3-year average	60.7	13.2					71.3	97	56.9	2,324	96

In Table VI and figure 14 a comparison is made of the average baking values of Montana spring wheats of the 1911 and 1912 crops with average commercial Nos. 1, 2, and 3 northern wheat. The commercial samples were secured at large terminal markets and represent in each case the average of 20 to 30 car lots for each of the grades. From the figures given here, the conclusion may be drawn that the

FIG. 14.—Comparison of bread from three grades of Minneapolis spring wheat with that of Montana-grown wheat, crop of 1912: *a*, *b*, and *c*, Nos. 1, 2, and 3 northern, Minneapolis; *d*, Fife (hard spring), Gallatin County; *e*, Fife, said to be hard winter, Gallatin County; *f*, Bluestem (hard spring), Valley County.

Montana wheat about equals average spring wheat in quality, except that as a rule the flour will not be found to rank as high in baking strength. What has been said of the winter wheat relative to strength applies equally well to the spring wheat, for, although the average is somewhat lower, about the same range in quality is observed in the spring wheat of other sections as is found in that grown in Montana.

TABLE VI.—*Baking tests of Montana hard spring wheats compared with average commercial Nos. 1, 2, and 3 northern, crops of 1911 and 1912.*

Class or type.	Number of samples.	Yield of straight flour.	Tests of straight flour.						Crude protein in wheat, N×5.7.	Moisture in wheat.
			Color of bread.	Absorption of water.	Strength.		Crude protein in flour, N×5.7.	Moisture in flour.		
					Volume of loaf.	Texture of loaf.				
		Per ct.	*Score.*	*Per ct.*	*C. c.*	*Score.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Crop of 1911:										
Montana hard red spring..	6	71.1	99	58.8	2,376	96	11.46	10.52	12.03	14.4
Average commercial spring wheat—										
No. 1 northern........	17	71.9	99	56.9	2,517	97	12.22	10.67	13.11	12.5
No. 2 northern........	15	70.4	99	57.0	2,561	97	12.18	10.41	13.17	13.0
No. 3 northern........	10	68.6	98	56.7	2,631	97	12.47	10.68	12.98	13.1
Crop of 1912:										
Montana hard red spring..	9	71.5	94	58.4	2,129	93	12.05	10.46	12.40	13.1
Average commercial spring wheat—										
No. 1 northern........	5	72.6	93	56.3	2,228	91	11.53	10.75	11.97	13.1
No. 2 northern........	5	71.3	92	56.4	2,246	93	11.69	10.99	12.34	13.1
No. 3 northern........	5	71.9	91	56.7	2,210	93	11.70	10.56	12.52	12.8

Figure 15 shows a comparison of the bread from Montana-grown wheat and that from a composite sample of Minneapolis No. 1 northern, crop of 1912: *a*, No. 1 northern, Minneapolis; *b*, Fife, Gallatin

County; *c*, Turkey, Yellowstone County; *d*, Bluestem, Valley County; *e*, Fife, Gallatin County, described as hard winter wheat; *f*, durum, Valley County.

WESTERN RED AND WHITE WHEAT.

Under the head of western wheat is properly classified the wheat of the soft varieties, both red and white. Commercially these wheats are conveniently separated under two classes. The western red class includes a number of varieties, of which Crail Fife is principally grown, and is an especial favorite in irrigated districts because of its large yields under this treatment. In general properties, the flour produced therefrom resembles flour from soft red wheat. A number of other varieties are grown within the State. Of these, one called Velvet Chaff resembles the Crail Fife wheat very closely in milling and baking quality. Galgalos is a peculiar variety which mills much like a soft wheat, producing a characteristic light, fluffy flour, but, on the other

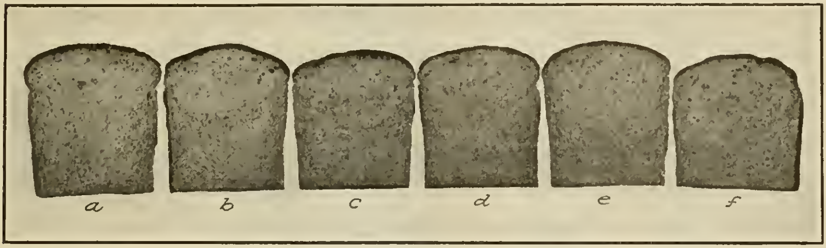


FIG. 15.—Comparison of bread from Montana-grown wheat with that from a composite sample of Minneapolis No. 1 northern wheat, crop of 1912: *a*, No. 1 northern, Minneapolis; *b*, Fife, Gallatin County, Mont.; *c*, Turkey, Yellowstone County; *d*, Bluestem, Valley County; *e*, Fife, Gallatin County, described as hard winter wheat; *f*, durum, Valley County.

hand, it is more glutinous and usually has better baking qualities. Crimean spring and Pringle Champlain are varieties which perhaps should be classified as hard spring wheat, but such results as so far have been secured indicate that they are inferior to the standard varieties, such as Fife and Bluestem. Complete milling and baking results with samples of these wheats are given in Table VII. Further information as to the condition of the individual samples and the commercial classification is given in Table VIII.

In Tables IX and X are presented similar results with Montana-grown white wheats. These varieties of white wheat are also largely grown upon irrigated lands and are of even a more starchy and softer character than the Crail Fife. Because of the light, fluffy nature of the flour it was very difficult to estimate accurately the quantity of flour that could be produced from this wheat with the milling machinery which was available. The yield figures should be considerably higher than those given in the tables. The flour of this wheat is very low in crude protein and in baking strength.

TABLE VII.—*Baking tests of Montana soft and semihard red wheats, showing sources of samples, variety, and milling quality for four successive years.*

Sample No.	County in which grown.	Variety.	Yield of straight flour.	Loss in milling.	Tests of straight flour.						Crude protein in wheat, N×5.7.	Moisture in wheat.
					Color of bread.	Absorption of water.	Strength.		Crude protein in flour, N×5.7.	Moisture in flour.		
							Volume of loaf.	Texture of loaf.				
			Per cent.	*Per cent.*	*Score.*	*Per cent.*	*C. c.*	*Score.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Crop of 1908:												
295 [a]	Gallatin	Crail Fife	65.8	5.3	102	51.5	1,740	....	8.78	7.73	9.92	11.5
356 [a]	Moore	do	72.9	2.5	102	52.4	1,900	....	10.03	....	9.98	9.7
Crop of 1909:												
510	Gallatin	do	67.3	4.4	94	50.3	1,970	....	11.34	10.90	12.08	13.0
Crop of 1910:												
728	do	do	66.6	5.4	102	48.5	1,930	93	10.60	10.70	10.89	11.9
Crop of 1911:												
1065	Fergus	Galgalos	62.3	4.6	95	60.9	2,180	94	14.82	8.98	16.53	14.4
1077 [b]	do	Crimean, spring	66.1	1.9	96	59.1	2,230	90	13.40	10.04	13.91	13.4
1072	Flathead	Velvet chaff, winter	68.6	6.5	99	58.2	1,780	85	9.86	10.19	9.98	13.8
1045	Gallatin	Pringle Champlain	80.0	0	94	57.6	2,010	89	11.34	9.41	11.97	12.6
1145	do	Crail Fife	70.4	[d] 1.6	96	53.5	1,460	80	10.83	11.00	11.97	11.9
1060 [b]	Broadwater	Pringle Champlain	73.3	1.7	92	60.3	2,180	94	15.16	8.80	15.96	11.2
1068 [b]	Park	do	70.8	2.9	94	57.9	1,890	90	10.77	9.90	10.55	13.6
912 [c]		Mixed	70.2	2.2	96	53.8	1,650	82	8.61	10.52	9.18	12.8
913 [c]		do	72.3	1.1	95	52.9	1,470	70	8.55	10.39	9.18	11.6
3-year average			68.5	3.4	98	53.6	1,787	84	10.38	10.05	11.08	12.3

[a] Baking tests with approximately a 70 per cent patent flour.
[b] Crimean spring and Pringle Champlain of doubtful classification. The average is exclusive of these samples.
[c] Sample 912, No. 1 western red, Minneapolis; 913, No. 1 western red, Duluth.
[d] Gain in milling.

TABLE VIII.—*Correlation of physical characters and milling quality of Montana soft and semihard wheats, showing the character, condition, and commercial classification of samples, crops of 1910 and 1911.*

Sample No.	Weight per bushel, cleaned.	Moisture in wheat.	Condition.	Commercial classification and grade.			Yield of straight flour.	Tests of straight flour.			
				Inspector A.	Inspector B.	Inspector C.		Color of bread.	Absorption of water.	Strength.	
										Volume of loaf.	Texture of loaf.
Crop of 1910:	*Pounds.*	*Per ct.*					*Per ct.*	*Score.*	*Per ct.*	*C. c.*	*Score.*
728	61	11.9	Badly bleached, plump	No. 2 western red		No.2 western red	66.6	102	48.5	1,930	93
Crop of 1911:											
1065	60	14.4	Bleached, plump	No. 1 western red	No. 3 durum	do	62.3	95	60.9	2,180	94
1077 [a]	57.5	13.4	Bleached, shrunken	No. 3 western red	No. 4 hard winter	No. 4 western red	66.1	96	59.1	2,230	90
1072	61	13.8	Bleached, plump	No. 1 western red	No. 3 western red	No. 3 western red	68.6	99	58.2	1,780	85
1045 [a]	61	12.6	Sound, plump	No. 1 northern	No. 1 western red	No. 1 northern	80.0	94	57.6	2,010	89
1145	62	11.9	do	No. 3 western red		No. 4 western red	70.4	96	53.5	1,460	80
1060 [a]	56	11.2	Sound, shrunken	No. 3 northern	No. 2 northern	No. 3 northern	73.3	92	60.3	2,180	94
1068 [a]	60	13.6	Sound, plump	No. 1 northern	No. 1 northern	No. 1 northern	70.8	94	57.9	1,890	90
912 [b]	63	12.8					70.2	96	53.8	1,650	82
913 [c]	63	11.6					72.3	95	52.9	1,470	70
2-year average	61.7	12.7					68.4	97	54.6	1,745	84

[a] Crimean spring and Pringle Champlain of doubtful classification. Average exclusive of these samples.
[b] 912 sample of No. 1 western red, Minneapolis, Minn
[c] 913 sample of No. 1 western red, Duluth, Minn.

TABLE IX.—*Baking tests of Montana white wheat, showing sources of samples, variety, and milling quality for five successive years.*

Sample No.	County in which grown.	Variety.	Yield of straight flour.	Loss in milling.	Tests of straight flour.						Crude protein in wheat, N×5.7.	Moisture in wheat.
					Color of bread.	Absorption of water.	Strength.		Crude protein in flour, N×5.7.	Moisture in flour.		
							Volume of loaf.	Texture of loaf.				
			Per cent.	*Per cent.*	*Score.*	*Per cent.*	*C. c.*	*Score.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Crop of 1908:												
296[a]	Gallatin	Fall Club	61.1	10.3	99	52.4	1,900	....	7.92	8.39	8.72	11.1
355[a]	Fergus	do	68.8	5.8	99	50.9	2,080	....	10.55	....	14.99	9.9
Crop of 1909:												
511	Gallatin	do	65.1	4.6	103	49.4	2,100	....	7.35	11.53	9.23	13.5
Crop of 1910:												
729	do	Spring Club	67.2	5.6	98	47.6	1,660	93	8.72	9.51	8.78	11.2
732	do	do	68.3	2.9	97	47.1	1,610	93	7.52	11.16	8.61	11.6
746	Fergus	Sonora	66.4	7.3	96	47.9	1,730	90	11.34	9.94	11.34	12.5
Crop of 1911:												
1047	Gallatin	Stanley spring	64.2	10.3	94	55.0	1,550	80	10.83	8.93	10.77	13.6
1055	Ravalli	Spring Club	66.8	6.4	90	53.2	1,695	86	9.12	9.52	9.86	14.2
1144	Gallatin	Club	71.2	2.9	96	52.6	1,800	88	9.41	10.89	9.98	11.6
911A[b]	....	....	70.1	2.4	94	52.9	1,760	82	10.20	9.59	10.60	11.8
Crop of 1912:												
1460	Gallatin	Fall Club	64.8	6.1	92	50.9	1,435	70	7.64	11.29	7.58	13.5
5-year average	....	....	66.7	5.9	96	50.9	1,756	85	9.16	9.98	10.12	12.2

[a] Baking tests with approximately a 70 per cent patent flour.

[b] No. 1 western white wheat secured at Minneapolis, Minn.

TABLE X.—*Correlation of physical characters and milling quality of Montana white wheat, showing condition and commercial grading of samples for three successive years.*

Sample No.	Weight per bushel cleaned.	Moisture in wheat.	Condition.	Commercial classification and grade.			Yield of straight flour.	Tests of straight flour.			
				Inspector A.	Inspector B.	Inspector C.		Color of bread.	Absorption of water.	Strength.	
										Volume of loaf.	Texture of loaf.
	Pounds.	*Per ct.*					*Per ct.*	*Score.*	*Per ct.*	*C. c.*	*Score.*
Crop of 1910:											
729	61.5	11.2	Bleached, plump	No. 1 western white.		No. 2 western white.	67.2	98	47.6	1,660	93
732	62.5	11.6	Sound, plump	do		No. 1 western white.	68.3	97	47.1	1,610	93
746	63	12.5	Sound, shrunken	do		No. 2 western white.	66.4	96	47.9	1,730	90
Crop of 1911:											
1047	60	13.6	Bleached, "frosted"	No. 2 western white.	No. 4 western white.	No. 4 western white.	64.2	94	55	1,550	80
1055	61	14.2	Shrunken, sound	No. 1 western white.	No. 2 western white.		66.8	90	53.2	1,695	86
1144	59	11.6	Bleached, fairly plump, "frosted"	No. 3 western white.		No. 3 western white.	71.2	96	52.6	1,800	88
911A	62	11.8			No. 1 western white.		70.1	94	52.9	1,760	82
Crop of 1912:											
1460	59	13.5	Bleached, shrunken, "frosted"	No. 2 western white.		No. 3 western white.	64.8	92	50.9	1,435	70
3-year average.	60.9	12.5					67.4	95	50.9	1,655	85

Table XI presents the results of baking tests of Montana soft red and white wheats of average quality as compared with average No. 2 red winter wheats grown in 1911 and 1912.

TABLE XI.—*Baking tests of Montana soft red and white wheats of average quality compared with average No. 2 red winter wheats, crops of 1911 and 1912.*

Character and class or type of samples.	Number of samples.	Yield of straight flour.	Tests of straight flour.						Crude protein in wheat, N×5.7.	Moisture in wheat.
			Color of bread.	Absorption of water.	Strength.		Crude protein in flour, N×5.7.	Moisture in flour.		
					Volume of loaf.	Texture of loaf.				
		Per ct.	*Score.*	*Per ct.*	*C. c.*	*Score.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Soft red wheat (western red), 4-year average, 1908–1911	13	68.5	98	53.6	1,787	84	10.38	10.05	11.08	12.3
Soft white wheat (western white), 5-year average, 1908–1912	11	66.7	96	50.9	1,756	85	9.16	9.98	10.12	12.2
Average commercial, No. 2 red winter, 1911 crop	43	69.4	98	52.9	1,989	93	9.90	9.89	10.72	11.4
Average commercial, No. 2 red winter, 1912 crop	20	69.4	95	51.6	1,853	91	8.65	10.50	9.47	12.7

MONTANA DURUM WHEAT.

Montana-grown durum wheat does not differ widely in any essential characteristic from the durum wheat grown in other sections.[1] It is very hard and flinty, and in grinding it a high percentage of a creamy or yellow flour is produced. The baking quality of this flour is usually somewhat poorer than that of hard winter wheat. As a rule, it contains a high percentage of crude protein. But two exceptions are noted to this in the samples examined, and, of these, one, No. 1067, contained a little less than 11 per cent of crude protein, while the second, No. 1469, contained about 9.5 per cent. The results of tests and a description of such durum wheat samples as were examined are to be found in Tables XII and XIII. Figure 12 affords a comparison of the bread from Montana durum wheat with that of other classes of wheat. As has already been suggested, durum wheat is admirably suited for the production of coarse flours and semolina for use in the manufacture of macaroni and other edible pastes. It is not especially suited for the production of white bread flours except for blending with the flours of other wheats. The yellow color of durum wheat is highly prized by the macaroni manufacturers.

[1] Ladd, E. F., and Bailey, C. H. Wheat investigations. Milling, baking and chemical tests. N. Dak. Agr. Exp. Sta. Bul. 89, p. 13–80. 1910.

——— ——— Wheat investigations. Milling, baking, and chemical tests. N. Dak. Agr. Exp. Sta. Bul. 93, p. 203–253. 1911.

TABLE XII.—*Baking tests of Montana durum wheat, showing source of the samples, variety, and milling quality for stated years.*

Sample No.	County in which grown.	Variety.	Yield of straight flour.	Tests of straight flour.							Crude protein in wheat, N×5.7.	Moisture in wheat.
				Loss in milling.	Color of bread.	Absorption of water.	Strength.		Crude protein in flour, N×5.7.	Moisture in flour.		
							Volume of loaf.	Texture of loaf.				
			Per cent.	*Per cent.*	*Score.*	*Per cent.*	*C. c.*	*Score.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Crop of 1908:												
357 [a]	Fergus		72.3	[b] 4.5	94	58.6	2,180	....	13.17	....	13.56	11.2
Crop of 1911:												
957	Custer	Kubanka	78.1	[b] 1.1	90	54.4	2,020	92	13.01	9.29	13.74	11.8
1,061	Broadwater	do	78.2	[b] .3	88	56.5	1,970	92	15.90	8.82	16.25	11.4
1,063	do	Pelessier	77.7	[b] .9	88	63.5	1,950	92	16.00	8.97	16.19	10.4
1,064	Fergus	Kubanka	78.5	[b] .8	78	57.1	2,000	88	15.75	10.16	16.70	14.5
1,067	Park		76.6	2.4	85	56.8	1,650	85	11.13	10.46	10.89	13.0
Crop of 1912:												
1,469	Valley		71.6	4.5	94	55.9	1,765	90	10.09	10.96	9.52	13.8
3-year average			76.1	[b] 2.1	88	57.6	1,934	90	13.58	9.78	13.84	12.3

[a] Baking tests with patent flour.

[b] Gain in milling.

TABLE XIII.—*Correlation of physical characters and milling quality of Montana durum wheat, showing condition and commercial classification of samples for 1911 and 1912.*

Sample No.	Weight per bushel, cleaned.	Moisture in wheat.	Condition.	Commercial classification and grade.			Yield of straight flour.	Tests of straight flour.			
				Inspector A.	Inspector B.	Inspector C.		Color of bread.	Absorption of water.	Strength.	
										Volume of loaf.	Texture of loaf.
Crop of 1911:	*Pounds.*	*Per ct.*					*Per ct.*	*Score.*	*Per ct.*	*C. c.*	*Score.*
957	60	11.8	Sound, fairly plump	No. 1 durum	No. 1 durum		78.1	90	54.4	2,020	92
1061	60	11.4	do	do	No. 2 durum		78.2	88	56.5	1,970	92
1063	60	10.4	do	do	No. 1 durum		77.7	88	63.5	1,950	92
1064	61	14.5	do	do	do		78.5	78	57.1	2,000	88
1067	61.5	13.0	Bleached, "frosted," fairly plump.	do	No. 2 durum		76.6	85	56.8	1,650	85
Average	60.5	12.2					77.8	86	57.6	1,918	90
Crop of 1912:											
1469	63.5	13.8	Sound, fairly plump	No. 1 durum		No. 1 durum	71.6	94	55.9	1,765	90

SUMMARY OF THE CHARACTERISTICS OF THE FIVE CLASSES OF MONTANA WHEAT.

Five distinct classes of wheat are produced in Montana, which may be conveniently designated as hard spring, hard winter, western red,

FIG. 16.—Comparison of the bread from three classes of Montana wheat, crop of 1911: *a*, Velvet Chaff (western red); *b*, Turkey, of unusual "strength," Fergus County; *c*, Fife, Meagher County; *d*, Fife, Flathead County; *e*, Cascade County, described as No. 1 northern; *f*, Cascade County, described as No. 2 northern.

western white, and durum. The two first-named classes are of about the same milling quality, except that the spring wheat is decidedly superior in baking strength. The wheats of these two classes also resemble each other closely in physical characteristics and composition; both are best suited for the production of a bread flour.

The flour from the western red and western white wheat is very low in strength and absorption and has the general characteristics of other soft-wheat flours. The flour is best adapted for the production of crackers and pastry products. The bread produced from this wheat is very close textured and heavy.

Durum wheat is decidedly different from the wheat of any other class. Although generally yielding a high percentage of flour, the flour is usually very creamy or yellow in color and consequently receives a low score for color.

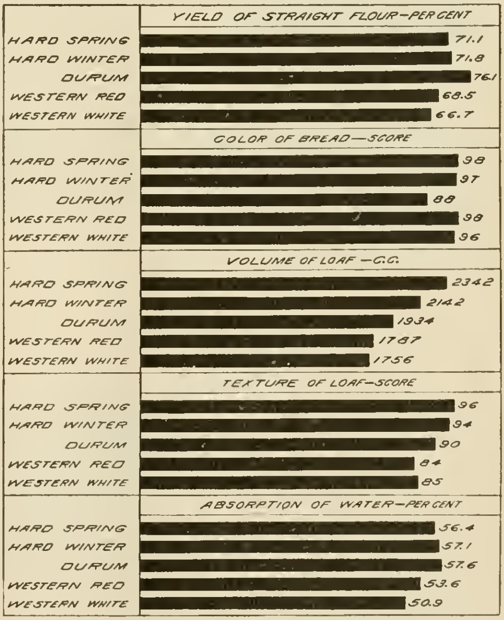


FIG. 17.—Diagram comparing the characteristics of the five groups of Montana-grown wheat.

In spite of the fact that the flour contains a very high percentage of crude protein, it falls between the hard winter and western red wheats in baking strength. In water absorption the flour is slightly superior to that of all other classes. The flour from this wheat is not popular for bread-making purposes on account of its creamy color, but it is especially adapted for the manufacture of macaroni and similar products.

TABLE XIV.—*Average of results of all baking tests of each of the five classes of Montana wheat.*

Class or type.	Number of samples.	Yield of straight flour.	Tests of straight flour.						Crude protein in wheat, N×5.7.	Moisture in wheat.
			Color of bread.	Absorption of water.	Strength.		Crude protein in flour, N×5.7.	Moisture in flour.		
					Volume of loaf.	Texture of loaf.				
		P. ct.	*Score.*	*P. ct.*	*C. c.*	*Score.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Hard red spring, 5-year average, 1908 to 1912	27	71.1	98	56.4	2,342	96	11.98	10.47	12.47	13.1
Hard red winter, 5-year average, 1908 to 1912	79	71.8	97	57.1	2,142	94	11.73	9.89	12.20	12.4
Durum, 3-year average, 1908, 1911, and 1912	7	76.1	88	57.6	1,934	90	13.58	9.78	13.84	12.3
Soft red winter (western red), 4-year average, 1908 to 1911	13	68.5	98	53.6	1,787	84	10.38	10.05	11.08	12.3
Soft white wheat (western white), 5-year average, 1908 to 1912	11	66.7	96	50.9	1,756	85	9.16	9.98	10.12	12.2

Typical loaves from the flour of three classes of Montana-grown wheat are shown in figure 16. A comparison of the average results of tests with the wheat of the five classes is presented in Table XIV and shown in figure 17.

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BULLETIN No. 523

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER June 29, 1917

UTILIZATION OF ASH

By

W. D. STERRETT, Forest Examiner

CONTENTS

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CONTENTS.

INTRODUCTION.

Ash is one of the leading commercial hardwoods of the United States. Its importance is due to the intrinsic qualities of its wood; for the quantity cut annually and the available supply of standing timber are small in comparison with the output and supply of a number of other American hardwoods. United States census figures for the last 15 years indicate that, in the production of lumber, ash ranks eleventh among hardwoods, the annual cut amounting to from $2\frac{1}{2}$ to 3 per cent of the hardwood lumber output and to less than 1 per cent of the total cut of all species. The peculiar merits of the wood, however, make it very valuable for a number of articles, such as handles, butter tubs, vehicles, and refrigerators. Thus it offers a wide range of possibilities for profitable utilization, and for that reason is an extremely desirable tree to encourage in woodlots.

The value of ash for different uses and the amount of the different species of ash used in various industries are given in this bulletin, and methods are indicated by which owners may utilize their ash timber profitably. This bulletin also contains an account of the properties of ash wood. The paragraphs on its mechanical properties are taken from a report by J. A. Newlin, engineer in the Forest Products Laboratory at Madison, Wis. Mr. Newlin's report is based on timber tests conducted by the laboratory on specimens mostly collected by the author. That part of the bulletin which deals with utilization by industries is based, for the most part, on studies of secondary wood-using industries in the different States carried on by the Office of Industrial Investigations of the Forest Service, from 1910 to 1913, inclusive.[1]

COMMERCIAL SPECIES.

There are 18 species of ash native to the United States, but 98 per cent of the ash lumber produced is from three species—white ash (*Fraxinus americana*), black ash (*F. nigra*), and green ash (*F. lanceolata*). The species which make up the remaining 2 per cent of the lumber output of ash are Oregon ash (*F. oregona*), blue ash (*F. quadrangulata*), Biltmore ash (*F. biltmoreana*), pumpkin ash (*F. profunda*), and red ash (*F. pennsylvanica*), all of which species have good cultural possibilities and are considered more important silviculturally than commercially. (Fig. 1.)

In the lumber trade ash lumber is often not distinguished as to kinds, all species being sold under the common name of ash. Much is sold under the name white ash to distinguish it from brown ash (also known as black ash, *F. nigra*), which has mechanical properties quite different from those of white ash but the same general appearance and structure and a more handsome grain. Lumber cut from all species, however, is often sold as white ash. The terms green, red, and Biltmore ash are not used at all in the lumber trade. Old-growth ash from continuously wet river bottom land is often called pumpkin ash because it is soft and brittle. The term is applied chiefly to pumpkin ash (*F. profunda*) and green ash (*F. lanceolata*). The terms black and blue ash are often used locally to designate standing ash timber, but do not necessarily refer to the species botanically known as *F. nigra* and *F. quadrangulata*. The term Oregon ash is seldom used in trade on the Pacific coast.

An estimate of the cut of ash by species in the different States is given in Table 1. The table is based on 1910 census data. From these data the cut of ash by counties was determined (see fig. 2), and careful estimates were made by the author of the proportion of each species in each county for which a report was made by the census. The table indicates roughly the commercial range of the important species.

[1] Compiled under the direction of J. C. Nellis, forest examiner.

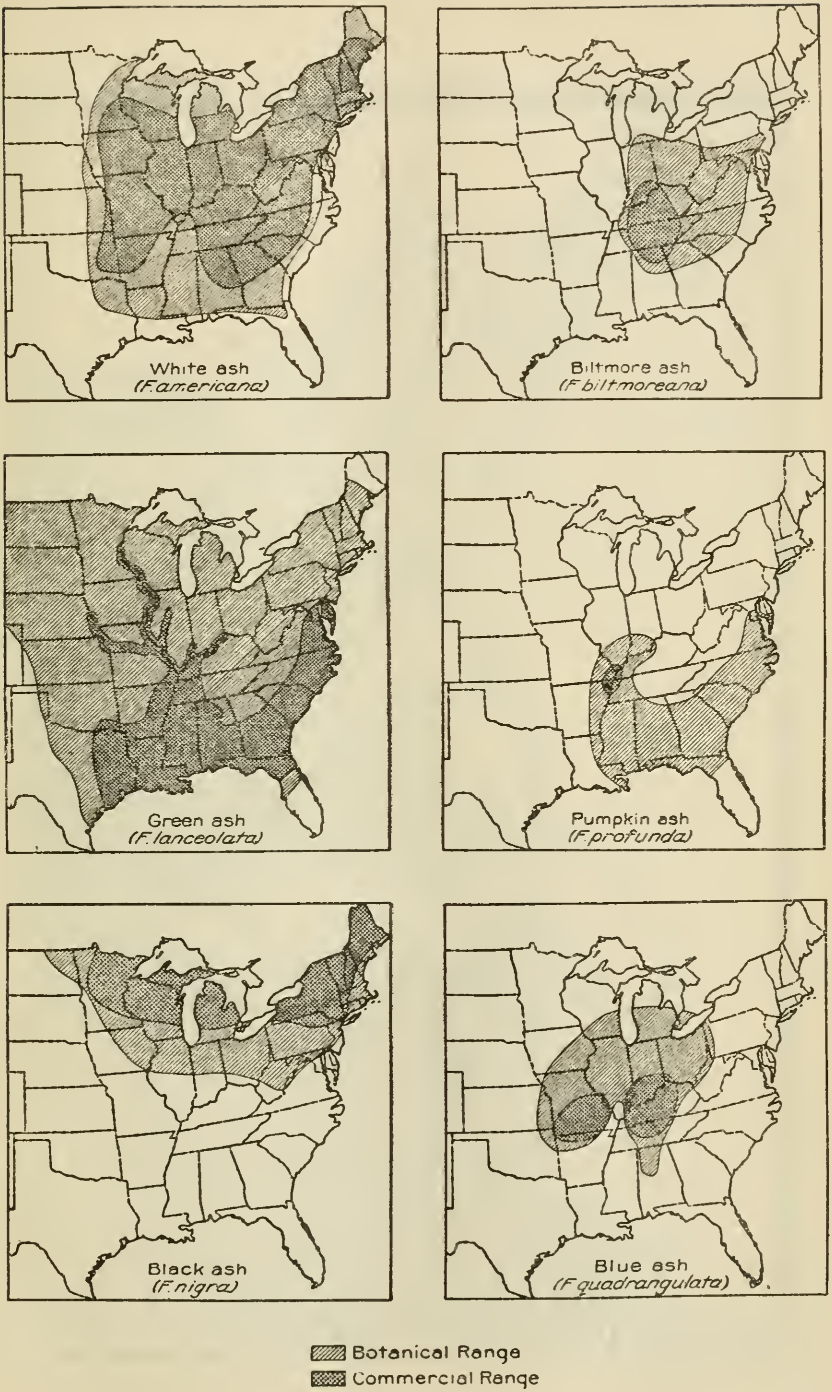


FIG. 1.—Commercial ashes. Data prepared by W. H. Lamb, of the Forest Service, and the author.

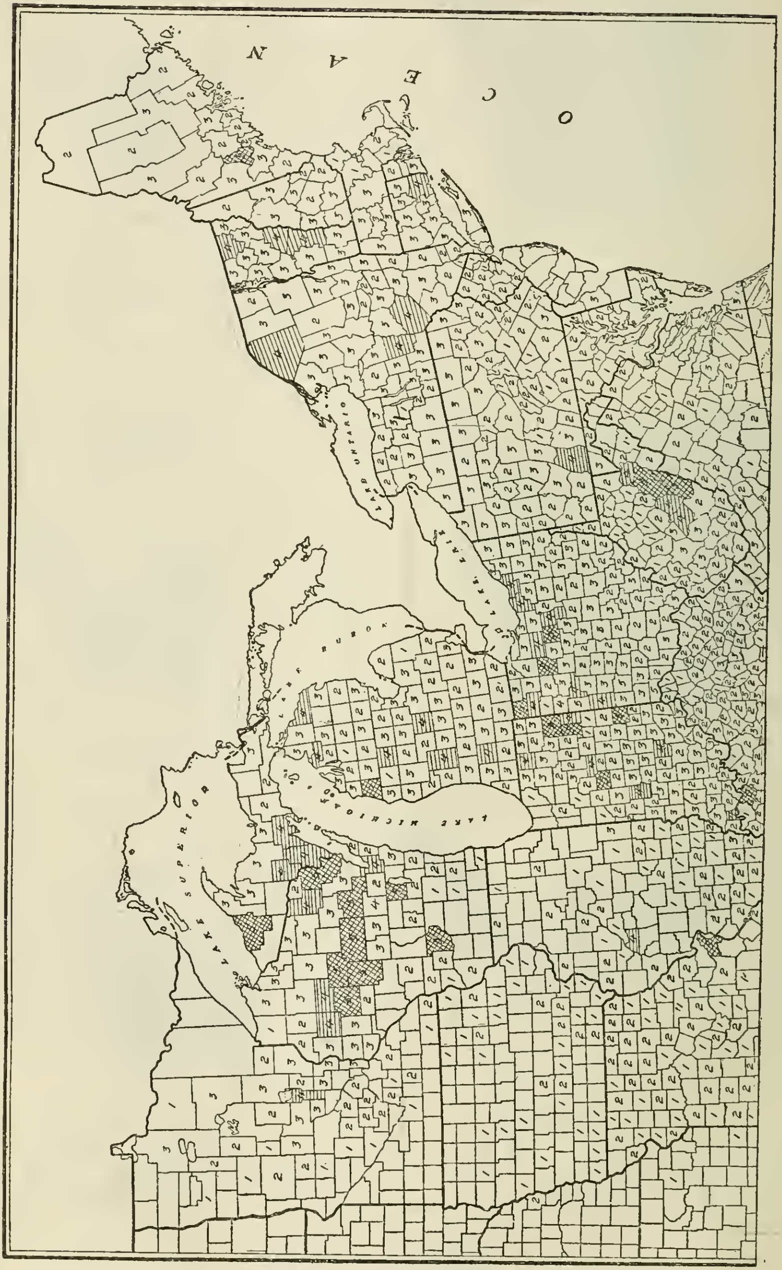
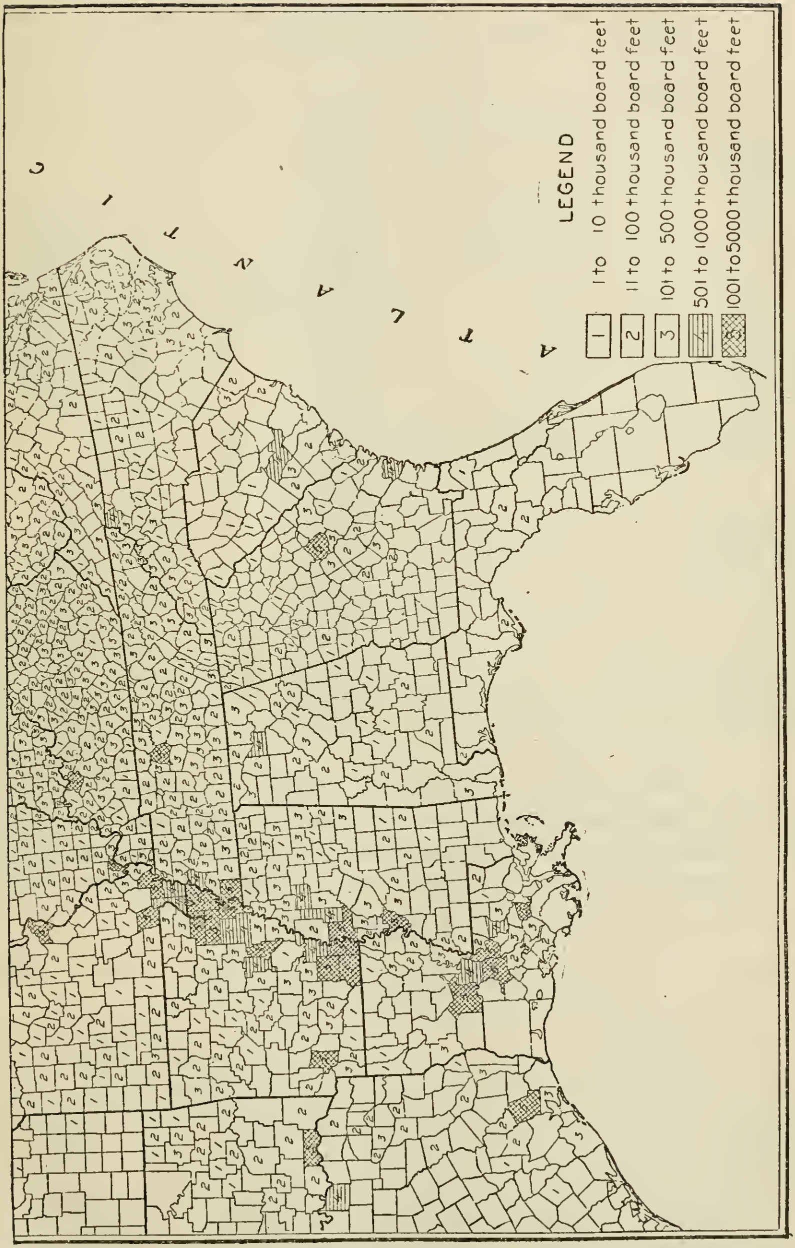


FIG. 2.—Lumber cut of



ash by counties, 1910.

TABLE 1.—*Estimated proportion contributed by the different species of ash to the total lumber cut of ash in 1910.*

	Total cut, 1910 (census figures).	Black.	White.	Green.	Oregon.
	Board feet.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Total for United States	234,715,000	17.9	44.7	37.1	03.
Alabama	2,146,000		20	80	
Arkansas	26,308,000		5	95	
Connecticut	1,893,000	5	95		
Delaware	1,000		100		
Florida	238,000		20	80	
Georgia	2,859,000		20	80	
Illinois	3,178,000		30	70	
Indiana	19,765,000	10	80	10	
Iowa	463,000		40	60	
Kansas and Nebraska	67,000			100	
Kentucky	8,943,000		60	40	
Louisiana	13,302,000		5	95	
Maine	3,104,000	20	80		
Maryland	548,000	5	85	10	
Massachusetts	1,656,000	10	90		
Michigan	19,513,000	60	40		
Minnesota	3,151,000	80	5	15	
Mississippi	8,901,000		20	80	
Missouri	12,560,000		25	75	
New Hampshire	1,695,000	20	80		
New Jersey	208,000	10	90		
New York	9,386,000	20	80		
North Carolina	3,426,000		70	30	
Ohio	22,815,000	20	70	10	
Oklahoma	2,977,000			100	
Pennsylvania	7,227,000	20	80		
Rhode Island	223,000		100		
South Carolina	1,650,000		10	90	
South Dakota	4,000			100	
Tennessee	15,043,000		60	40	
Texas	3,630,000			100	
Vermont	4,394,000	20	80		
Virginia	2,988,000		60	40	
West Virginia	7,183,000		95	5	
Wisconsin	22,670,000	70	25	5	
California	206,000				100
Oregon	299,000				100
Washington	95,000				100

Table 2 shows the proportion of ash lumber contributed by the important species in different years. It is to be noted that the proportion of black ash in 1914 was only half of what it was in 1899, while the proportion of green ash had nearly doubled in that time and the proportion of white ash had been reduced.

TABLE 2.—*Proportion of the ash lumber cut in the United States contributed by the different species* [1] *in different years.*

Species.	1899	1909	1910	1912	1914	1915
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Black ash	28.3	17.6	17.9	15.0	13.9	10.4
Green ash [1]	25.3	36.6	37.1	38.6	43.9	43.6
White ash [1]	45.0	45.6	44.7	45.9	41.7	45.9
Oregon ash	1.4	0.2	0.3	0.5	0.5	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

[1] Under white ash is included a small proportion of Biltmore and blue ash, and under green ash a small proportion of pumpkin and red ash. This table is based on census data using the proportion of species given in Table 1.

Table 3 shows the proportion of the ash lumber cut derived from the important species in different regions of the United States in 1910.

TABLE 3.—*Proportion of the ash lumber cut of 1910 derived from the important species in different regions.*

Region.	Per cent of total cut in United States.	Total cut in the region in board feet.	Per cent of total in region.		
			White ash.[1]	Green ash.[2]	Black ash.
New England	5.5	12,965,000	83.8	....	16.2
Middle Atlantic States	7.4	17,370,000	80.3	0.3	19.4
Lake States (Michigan, Wisconsin, Minnesota)	19.3	45,334,000	30.1	3.5	66.4
Ohio, Indiana, Illinois, West Virginia, Kentucky, Tennessee	32.8	76,927,000	70.1	21.4	8.5
South Atlantic States and Alabama	5.7	13,307,000	40.6	59.4	....
Lower Mississippi Valley, including Missouri, Arkansas, Oklahoma, Texas, Louisiana, and Mississippi	28.8	67,678,000	10.2	89.8	....
Kansas, Nebraska, Iowa, and South Dakota	.2	534,000	34.6	65.4	....
Washington, Oregon, California [3]	.3	600,000	....	....	....
Total	100.0	234,715,000	44.7	37.1	17.9

[1] Includes small per cent of Biltmore and blue ash.
[2] Includes small per cent of pumpkin and red ash.
[3] All Oregon ash.

Table 3 shows white ash to be the important species in New England, the Middle Atlantic, and the Central States; green ash in the South Atlantic States, the lower Mississippi Valley, and in Iowa, Kansas, Nebraska, and South Dakota; and black ash in the Lake States—Michigan, Wisconsin, and Minnesota. Over half the total supply of white ash comes from the Central States, 70 per cent of the green ash comes from the lower Mississippi Valley, and 71.5 per cent of the black ash from the Lake States. Over 60 per cent of the total supply of ash comes from the central and lower Mississippi Valley States, 19 per cent from the Lake States, 13 per cent from New England and Middle Atlantic States, and only 5.7 per cent from the South Atlantic States.

DEMAND AND SUPPLY.

QUANTITY USED ANNUALLY.

Practically all of the ash cut each year is required for use in so called secondary wood-using industries, which take the sawed lumber and, to a less extent, material in the rough form of logs and bolts, and use it in the manufacture of handles, butter tubs, vehicles, planing-mill products, etc. Table 4 indicates the present annual demand for ash in these industries and its distribution by States. According to this table a larger amount of ash was used in these industries than the census reported as being manufactured into lumber and cooperage stock. (See p. 8.) The excess is probably due to the manufacture of handles, butter tubs, and vehicle stock directly from logs and bolts.

TABLE 4.—*Ash used by secondary industries in the United States.*

State.	Quantity used annually.	State.	Quantity used annually.
	Feet b. m.		*Feet b. m.*
Illinois	51,311,000	Oklahoma	1,818,500
Michigan	33,220,619	West Virginia	1,763,300
Ohio	29,029,703	Louisiana	1,756.450
Arkansas	24,183,000	New Jersey	1,551,254
Iowa	19,827,442	South Carolina	1,518,000
Indiana	17.727,237	North Carolina	1,417,000
New York	17,556,225	Maryland	922,675
Wisconsin	14,339,000	California	816,798
Pennsylvania	14,304,627	Oregon	466,800
Missouri	10,528,675	Delaware	387,543
Tennessee	7,769,000	Kansas	287,629
Minnesota	6,280,592	Florida	280,163
Kentucky	4,498,500	Rhode Island	250,250
Maine	4,487,600	Nebraska	172,493
Virginia	4,182,403	Washington	130,900
Massachusetts	3,601,500	Colorado	130,650
New Hampshire	3,540,552	District of Columbia	107,800
Vermont	3,137,087	Utah	25,000
Connecticut	2,995,198	Arizona	5,500
Texas	2,393,940	Idaho	500
Alabama	2,330,500		
Georgia	2,236,877	Total	295,461,482
Mississippi	2,171,000		

THE ANNUAL CUT.

The census returns for the past decade indicate an annual cut of from two hundred to three hundred million feet of ash lumber. In rank in lumber production ash stands twentieth or twenty-first among all species. In addition to the lumber cut, from twenty-five to thirty-five million board feet[1] of ash is reported[2] to be used annually in slack cooperage for staves, heading, and hoops. The total annual cut of lumber and cooperage stock appears to be about the same for ash as for hickory or cottonwood.[2]

TABLE 5.—*Output of ash lumber, by States, in 1899 and from 1904 to 1915, inclusive, in 1,000 board feet; and average value of the product, f. o. b. mills in the United States.*

	1899	1904	1905	1906	1907	1908
Total number of mills reporting	31,833	18,277	11,666	22,393	28,850	31,231
Total number of mills cutting ash	....	....	2,653	....	5,454	6,012
Average value per 1,000 board feet. f. o. b. mill	$15.84	$18.77	....	$24.35	$25.01	$25.51
Total cut of ash	*1,000 board feet.* 269,120	*1,000 board feet.* 169,178	*1,000 board feet.* 159,634	*1,000 board feet.* 214,460	*1,000 board feet.* 252,040	*1,000 board feet.* 225,367
Alabama	5,782	2,641	1,071	2,377	3,366	1,277
Arkansas	15,624	14,586	13,034	20,571	23,801	21,086
California	....	....	....	....	....	10
Connecticut	158	292	904	2,118	1,884	1,535
Delaware	....	....	50	3	7	105
Florida	462	167	85	370	370	113
Georgia	992	426	553	967	1,320	1,605
Illinois	1,075	899	873	1,781	1,869	1,804
Indiana	27,603	25,606	13,340	19,631	19,359	19,997
Iowa	347	115	....	848	422	302
Kansas and Nebraska	26	....	....	....	....	....
Kentucky	4,877	4,246	12,939	8,999	10,405	8,629

[1] Mostly from green ash in the lower Mississippi Valley.
[2] According to census reports.

F-31063

FIG. 1.—OLD GROWTH WHITE ASH IN THE SOUTHERN APPALACHIANS.
Very valuable for large dimension stock.

F-13920A

FIG. 2.—SIXTY-YEAR-OLD SECOND GROWTH WHITE ASH STAND IN CENTRAL OHIO.

F-1WDS

FIG. 1.—GREEN ASH LOGS CUT FOR SEVERAL MONTHS. NORTHEASTERN ARKANSAS.

Note checking.

F-13345A

FIG. 2.—LARGE FELLED BLACK ASH TREE OF GOOD QUALITY AND GROWTH. NORTHERN MICHIGAN.

TABLE 5.—*Output of ash lumber, by States, in 1899 and from 1904 to 1915, inclusive, in 1,000 board feet; and average value of the product, f. o. b. mills in the United States*—Continued.

	1899	1904	1905	1906	1907	1908
	1,000 board feet.	*1,000 board feet.*	*1,000 board feet*	*1,000 board feet.*	*1,000 board feet.*	*1,000 board feet.*
Louisiana	4,979	2,987	1,493	3,382	7,586	7,976
Maine	1,259	105	1,279	1,667	4,912	3,136
Maryland	3	1	601	804	1,044	729
Massachusetts	120	2,281	614	2,017	2,032	2,214
Michigan	85,753	34,925	26,141	24,500	27,281	21,091
Minnesota	3,690	228	2,063	2,724	3,487	3,810
Mississippi	10,144	15,499	8,083	8,850	9,387	11,225
Missouri	10,458	5,356	4,308	7,972	10,067	9,068
New Hampshire	1,248	796	1,390	2,824	2,648	3,035
New Jersey	11	3	120	115	184	117
New York	8,956	2,796	9,900	15,585	16,175	15,293
North Carolina	3,617	3,833	4,111	4,769	4,834	3,829
Ohio	28,934	13,082	10,539	21,359	22,501	20,938
Oklahoma	100	1,840	....	....	893	3,802
Oregon	610	....	1,530	1,516	778	789
Pennsylvania	4,677	2,448	6,691	9,484	12,568	7,716
Rhode Island	34	....	159	240	545	223
South Carolina	1,371	4,213	7,460	1,636	2,934	5 190
Tennessee	18,100	8,950	5,819	12,404	19,099	15,490
Texas	6,793	2,826	1,988	2,824	2,960	1,459
Vermont	1,200	3,471	3,269	5,184	5,152	4,035
Virginia	1,060	291	656	2,362	3,267	1,411
Washington	3,203	150	205	11	289	390
West Virginia	2,207	2,729	2,938	4,895	9,003	7,534
Indian Territory	13,647	10,915	14,588	19,386	19,571	18,309
Wisconsin	....	....	440	285	....	....
All other States	....	....	....	....	40	95

	1909	1910	1911	1912	1913	1914	1915
Total number of mills reporting	48,112	31,934	28,107	29,648	21,668	27,750	16,815
Total number of mills cutting ash	8,930	6,944	6,348	6,491	3,348	3,649	3,486
Average value per 1,000 board feet f. o. b. mill	$24.44	$22.47	$21.21	$20.27	....	....	$22.15
	1,000 board feet.	*1,000 board feet.*	*1,000 board feet.*	*1,000 board feet.*	*1,000 board feet.*	*1,000 board feet.*	*1,000 board feet.*
Total cut of ash	291,209	234,715	214,398	234,548	207,816	189,499	159,910
Alabama	3,387	2,146	2,267	1,974	1,394	1,917	1,736
Arkansas	33,212	26,308	20,138	23,681	31,019	18,172	18,957
California	....	206	150	210	350	....	....
Connecticut	1,684	1,893	1,947	1,414	754	1,057	441
Delaware	61	1	2	25	50	5	2
Florida	282	238	208	290	2,042	964	2,163
Georgia	3,106	2,859	1,987	2,838	3,088	2,437	2,605
Illinois	2,894	3,178	2,244	2,774	1,860	6,017	2,520
Indiana	23,488	19,765	19,219	21,549	15,517	11,014	11,006
Iowa	788	463	557	442	138	100	234
Kansas and Nebraska	116	67	6	37	7	....	....
Kentucky	14,958	8,943	7,376	9,588	9,066	5,622	6,966
Louisiana	11,200	13,303	15,509	14,395	17,473	19,515	14,602
Maine	2,572	3,104	2,919	3,169	3,514	1,972	1,584
Maryland	2,166	548	743	555	92	178	225
Massachusetts	2,879	1,656	1,865	1,628	881	1,361	883
Michigan	24,865	19,513	14,127	14,280	8,681	8,893	7,839
Minnesota	3,326	3,151	2,978	3,235	1,480	2,009	2,264
Mississippi	15,017	8,901	6,443	9,051	9,914	8,086	7,381
Missouri	12,685	12,560	9,560	6,298	10,969	6,204	5,258
New Hampshire	2,554	1,695	1,637	1,759	903	1,155	1,090
New Jersey	183	208	236	175	60	274	318
New York	12,747	9,386	10,727	10,706	9,928	11,534	7,163
North Carolina	4,476	3,426	3,197	5,473	2,649	6,401	3,421
Ohio	25,753	22,815	21,995	26,100	12,967	10,717	8,618
Oklahoma	2,879	2,977	3,095	7,201	706	2,008	879
Oregon	455	299	149	884	146	809	100
Pennsylvania	9,814	7,227	9,368	10,336	5,742	6,980	5,625
Rhode Island	236	223	58	220	152	410	49
South Carolina	2,219	1,650	1,652	791	2,862	1,992	1,775
South Dakota	12	4	3	....	....	....	....
Tennessee	18,709	15,043	15,331	18,434	22,943	18,837	15,233
Texas	5,348	3,630	3,490	3,283	3,371	3,845	4,690
Vermont	4,531	4,394	4,244	3,971	2,990	4,428	3,188
Virginia	5,590	2,988	2,522	4,881	1,489	2,681	1,371
Washington	215	95	70	92	....	75	80
West Virginia	9,171	7,183	8,371	8,110	9,761	6,520	5,911
Wisconsin	27,631	22,670	18,008	14,699	12,858	15,310	13,733

TABLE 6.—*Average value of ash lumber per 1,000 board feet f. o. b. mills, in different States, from 1906 to 1911, inclusive, and 1915.*

	1906	1907	1908	1909	1910	1911	1915
Alabama	....	....	....	$25.00	$19.46	$18.67	$24.79
Arkansas	$28.38	$25.31	$22.08	24.35	22.20	20.60	23.35
California	....	....	....	....	50.00	....	....
Connecticut	....	....	....	....	25.85	21.36	19.15
Delaware	....	....	....	....	....	....	....
Florida	....	....	....	....	30.75	....	16.02
Georgia	....	....	....	23.76	18.98	17.94	21.56
Illinois	....	....	....	....	22.62	23.83	19.51
Indiana	26.86	29.87	34.22	30.55	25.89	24.44	23.75
Iowa	....	....	....	....	27.42	24.75	30.66
Kansas and Nebraska	....	....	....	....	....	....	....
Kentucky	23.51	22.93	22.81	21.85	21.65	20.89	23.69
Louisiana	....	27.43	23.11	21.75	20.77	21.36	22.47
Maine	....	....	....	....	19.73	17.44	18.54
Maryland	....	....	....	....	19.98	19.14	18.58
Massachusetts	....	....	....	....	21.45	20.47	18.79
Michigan	20.37	21.35	20.10	20.56	22.18	21.87	21.36
Minnesota	....	....	....	15.31	16.65	16.60	14.80
Mississippi	25.06	29.54	27.32	29.16	24.50	21.50	22.51
Missouri	29.20	32.08	39.00	23.34	25.32	20.84	21.75
New Hampshire	....	....	....	....	21.85	20.50	18.18
New Jersey	....	....	....	....	33.45	23.33	25.79
New York	24.00	18.00	31.00	23.00	22.76	21.46	23.90
North Carolina	26.48	....	....	17.96	15.85	17.50	20.11
Ohio	29.50	30.77	30.42	32.41	25.31	23.57	24.59
Oklahoma	....	....	....	....	23.85	....	20.87
Oregon	....	....	....	....	25.56	17.33	27.10
Pennsylvania	25.33	24.50	25.23	23.57	23.61	21.60	18.65
Rhode Island	....	....	....	....	26.33	....	25.97
South Carolina	....	....	20.95	....	23.07	17.50	20.19
South Dakota	....	....	....	....	....	....	....
Tennessee	26.43	27.05	25.85	30.88	20.75	20.17	23.37
Texas	....	....	....	23.36	24.84	22.17	23.93
Vermont	20.46	19.96	....	19.94	19.12	20.25	18.33
Virginia	....	....	....	18.29	19.00	20.00	18.18
Washington	....	....	....	....	25.00	....	25.25
West Virginia	....	26.10	28.40	25.46	22.80	21.23	21.20
Wisconsin	18.80	19.83	19.44	18.21	19.73	18.73	19.96
All other States	21.73	23.93	20.88	22.23	....	....	....

TABLE 7.—*Number of mills reporting lumber cut of ash in the different States.*

	1905	1907	1908	1909	1910	1911	1912	1913	1914	1915
Total	2,653	5,454	6,012	8,930	6,944	6,348	6,491	3,348	3,649	3,486
Alabama	....	....	42	97	65	64	62	18	33	29
Arkansas	88	196	151	258	166	150	157	92	111	87
California	....	....	1	....	4	1	1	1	....	....
Connecticut	....	....	122	154	130	117	97	51	68	50
Delaware	....	....	2	3	1	1	1	1	1	1
Florida	....	....	4	10	5	5	6	8	6	6
Georgia	....	....	59	68	52	49	57	23	30	21
Illinois	....	....	164	213	154	133	152	41	53	37
Indiana	279	486	584	733	581	461	516	233	251	238
Iowa	....	....	44	126	80	76	74	14	6	38
Kansas and Nebraska	....	....	4	2	4	2	4	1	....	....
Kentucky	157	399	450	583	483	376	412	161	131	156
Louisiana	....	41	36	49	43	54	50	47	65	49
Maine	....	....	165	184	142	123	132	92	92	82
Maryland	....	....	42	68	50	28	35	6	17	17
Massachusetts	....	....	152	157	104	115	112	32	58	64
Michigan	253	441	477	608	459	432	412	184	150	174
Minnesota	....	....	143	207	163	133	140	67	48	52
Mississippi	68	104	136	164	132	79	104	65	95	79
Missouri	....	150	232	354	282	235	238	87	55	68
New Hampshire	....	....	146	138	106	92	106	21	50	49
New Jersey	....	....	22	25	25	32	19	6	19	29
New York	....	....	....	963	743	897	690	927	809	702
North Carolina	....	....	152	192	164	145	163	65	68	77
Ohio	280	515	621	927	673	584	720	295	338	273
Oklahoma	....	....	56	80	59	52	64	17	47	18
Oregon	....	....	15	14	11	5	9	4	3	1
Pennsylvania	237	612	593	754	566	526	606	186	295	297

TABLE 7.—*Number of mills reporting lumber cut of ash in the different States*—Continued.

	1905	1907	1908	1909	1910	1911	1912	1913	1914	1915
Rhode Island	....	....	17	18	13	8	10	6	8	4
South Carolina	12	....	12	20	20	18	20	13	15	15
South Dakota	....	....	....	1	1	1	....	....	....	....
Tennessee	154	347	384	516	396	378	366	170	237	193
Texas	....	....	18	36	27	25	26	20	22	29
Vermont	....	223	210	221	221	231	228	90	133	151
Virginia	....	....	100	181	158	154	122	38	58	51
Washington	....	....	6	4	3	2	2	....	1	1
West Virginia	....	209	207	288	250	226	224	82	86	135
Wisconsin	203	382	443	514	408	338	344	184	187	213
All other States	922	1,349	....	....	....	....	....	....	....	....

The output of ash lumber by States for the year 1899 and the years 1904 to 1914, inclusive, and the average price[1] received for the product f. o. b. mills in the United States, are shown in Table 5; and the average f. o. b. mill values in different States for 1906 to 1911, inclusive, in Table 6. The figures for 1899 and 1909 are the most complete, as they are based on decennial census returns; those for 1904, 1905, and 1906 are the least complete. The comparative completeness of the figures for each year is indicated to a certain extent by the total number of mills reporting, as given in Table 5, and the number of mills reporting lumber cuts of ash in the different States, as given in Table 7. There are a number of important points to be observed in these tables. First, that the annual production of ash was maintained or somewhat increased during the decade from 1900 to 1909, but since that time it has considerably decreased. Again, in average f. o. b. value per thousand board feet there was an increase of 54 per cent in 1909 over 1899. That this increase was not maintained during succeeding years is due largely to an increased proportion of lower grades in the total output. A general survey of the present supply of ash timber leads to the conclusion that the high-water mark in the production of ash lumber in the United States, both in regard to quantity and quality of output, has been passed, and it is not likely that either the amount or value of the 1909 cut will ever again be equaled.

Table 8 indicates the constant shifting in rank of the ash-producing States. In 1899 the cut in Michigan (which was from virgin forests) was greater than in any other three States, while in 1911 Michigan had dropped to seventh place in the production of ash lumber, with an output one-sixth as great as that of 1899. Ohio and Indiana, where the cut is now entirely from second growth, ranked third and fifth, respectively, in 1909, but rose to first and third places in 1911 and 1912, although in each case there was considerable decrease in the actual amount of the output.

[1] United States census reports.

TABLE 8.—*Rank of the different States in amount of ash lumber produced in the year 1899 and the years 1904 to 1915, inclusive.*

Rank.	1899	1904	1905	1906
1	Michigan	Michigan	Michigan	Michigan.
2	Ohio	Indiana	Wisconsin	Ohio.
3	Indiana	Mississippi	Indiana	Arkansas.
4	Tennessee	Arkansas	Arkansas	Indiana.
5	Arkansas	Ohio	Kentucky	Wisconsin.
6	Wisconsin	Wisconsin	Ohio	New York.
7	Missouri	Tennessee	New York	Tennessee.
8	Mississippi	Missouri	Mississippi	Pennsylvania.
9	New York	Kentucky	South Carolina	Kentucky.
10	Texas	South Carolina	Pennsylvania	Mississippi.
11	Alabama	North Carolina	Tennessee	Missouri.
12	Louisiana	Vermont	Missouri	Vermont.
13	Kentucky	Louisiana	North Carolina	West Virginia.
14	Pennsylvania	Texas	Vermont	North Carolina.
15	Minnesota	New York	West Virginia	Louisiana.
16	North Carolina	West Virginia	Minnesota	Texas.
17	Washington	Alabama	Texas	New Hampshire.
18	West Virginia	Pennsylvania	Oregon	Minnesota.
19	South Carolina	Massachusetts	Louisiana	Alabama.
20	Maine	Oklahoma	New Hampshire	Virginia.
21	New Hampshire	Illinois	Maine	Connecticut.
22	Vermont	New Hampshire	Alabama	Massachusetts.
23	Illinois	Georgia	Connecticut	Illinois.
24	Virginia	Connecticut	Illinois	Maine.
25	Georgia	Virginia	Virginia	South Carolina.
26	Oregon	Minnesota	Massachusetts	Oregon.
27	Florida	Florida	Maryland	Georgia.
28	Iowa	Washington	Georgia	Iowa.
29	Connecticut	Iowa	(Indian Territory)	Maryland.
30	Massachusetts	Maine	Washington	Florida.
31	Oklahoma	New Jersey	Rhode Island	(Indian Territory.)
32	Rhode Island	Maryland	New Jersey	Rhode Island.
33	Kansas and Nebraska		Florida	New Jersey.
34	New Jersey		Delaware	Washington.
35	Maryland			Delaware.

Rank.	1907	1908	1909	1910
1	Michigan	Michigan	Arkansas	Arkansas.
2	Arkansas	Arkansas	Wisconsin	Ohio.
3	Ohio	Ohio	Ohio	Wisconsin.
4	Wisconsin	Indiana	Michigan	Indiana.
5	Indiana	Wisconsin	Indiana	Michigan.
6	Tennessee	Tennessee	Tennessee	Tennessee.
7	New York	New York	Mississippi	Louisiana.
8	Pennsylvania	Mississippi	Kentucky	Missouri.
9	Kentucky	Missouri	New York	New York.
10	Missouri	Kentucky	Missouri	Kentucky.
11	Mississippi	Louisiana	Louisiana	Mississippi.
12	West Virginia	Pennsylvania	Pennsylvania	Pennsylvania.
13	Louisiana	West Virginia	West Virginia	West Virginia.
14	Vermont	South Carolina	Virginia	Vermont.
15	Maine	Vermont	Texas	Texas.
16	North Carolina	North Carolina	Vermont	North Carolina.
17	Minnesota	Minnesota	North Carolina	Illinois.
18	Alabama	Oklahoma	Alabama	Minnesota.
19	Virginia	Maine	Minnesota	Maine.
20	Texas	New Hampshire	Georgia	Virginia.
21	South Carolina	Massachusetts	Illinois	Oklahoma.
22	New Hampshire	Illinois	Massachusetts	Georgia.
23	Massachusetts	Georgia	Maine	Alabama.
24	Connecticut	Connecticut	New Hampshire	Connecticut.
25	Illinois	Texas	South Carolina	New Hampshire.
26	Georgia	Virginia	Maryland	Massachusetts.
27	Maryland	Alabama	Connecticut	South Carolina.
28	Oklahoma	Oregon	Iowa	Maryland.
29	Oregon	Maryland	Oregon	Iowa.
30	Rhode Island	Washington	Florida	Oregon.
31	Iowa	Iowa	Rhode Island	Florida.
32	Florida	Rhode Island	Washington	Rhode Island.
33	Washington	New Jersey	New Jersey	New Jersey.
34	New Jersey	Florida	Kansas and Nebraska.	California.
35	Delaware	Delaware	Delaware	Washington.
36		California	South Dakota	Kansas and Nebraska.
37				South Dakota.
38				Delaware.

TABLE 8.—*Rank of the different States in amount of ash lumber produced in the year 1899 and the years 1904 to 1915, inclusive*—Continued.

Rank.	1911	1912	1913	1914	1915
1	Ohio	Ohio	Arkansas	Louisiana	Arkansas.
2	Arkansas	Arkansas	Tennessee	Tennessee	Tennessee.
3	Indiana	Indiana	Louisiana	Arkansas	Louisiana.
4	Wisconsin	Tennessee	Indiana	Wisconsin	Wisconsin
5	Tennessee	Wisconsin	Ohio	New York	Indiana.
6	Louisiana	Louisiana	Wisconsin	Indiana	Ohio.
7	Michigan	Michigan	Missouri	Ohio	Michigan.
8	New York	Pennsylvania	New York	Michigan	Mississippi.
9	Missouri	New York	Mississippi	Mississippi	New York.
10	Pennsylvania	Kentucky	West Virginia	Pennsylvania	Kentucky.
11	West Virginia	Mississippi	Kentucky	West Virginia	West Virginia.
12	Kentucky	West Virginia	Michigan	North Carolina	Pennsylvania.
13	Mississippi	Oklahoma	Pennsylvania	Missouri	Missouri.
14	Vermont	Missouri	Maine	Illinois	Texas.
15	Texas	North Carolina	Texas	Kentucky	North Carolina.
16	North Carolina	Virginia	Georgia	Vermont	Vermont.
17	Oklahoma	Vermont	Vermont	Texas	Georgia.
18	Minnesota	Texas	South Carolina	Virginia	Illinois.
19	Maine	Minnesota	North Carolina	Georgia	Minnesota.
20	Virginia	Maine	Florida	Minnesota	Florida.
21	Alabama	Georgia	Illinois	Oklahoma	South Carolina.
22	Illinois	Illinois	Virginia	South Carolina	Alabama.
23	Georgia	Alabama	Minnesota	Maine	Maine.
24	Connecticut	New Hampshire	Alabama	Alabama	Virginia.
25	Massachusetts	Massachusetts	New Hampshire	Massachusetts	New Hampshire.
26	South Carolina	Connecticut	Massachusetts	New Hampshire	Massachusetts.
27	New Hampshire	Oregon	Connecticut	Connecticut	Oklahoma.
28	Maryland	South Carolina	Oklahoma	Florida	Connecticut.
29	Iowa	Maryland	California	Oregon	New Jersey.
30	New Jersey	Iowa	Rhode Island	Rhode Island	Iowa.
31	Florida	Florida	Oregon	New Jersey	Maryland.
32	California	Rhode Island	Iowa	Maryland	Oregon.
33	Oregon	California	Maryland	Iowa	Washington.
34	Washington	New Jersey	New Jersey	Washington	Rhode Island.
35	Rhode Island	Washington	Delaware	Delaware	Delaware.
36	Kansas and Nebraska.	Kansas and Nebraska.	Kansas and Nebraska.		
37	South Dakota	Delaware			
38	Delaware				

These changes indicate the waning importance of old growth as compared with second growth. The decline in total production is a result of the inability of the second growth to keep pace with the annual cut. This condition will be increasingly marked as the supply of old growth disappears. Since 1912 the lower Mississippi Valley States, Arkansas, Louisiana, and Tennessee, which cut about half and half from old and young growth, have been in the lead.

Table 9 indicates the proportion of the ash lumber cut contributed by different regions in the United States for the years 1899, 1909, 1910, 1912, and 1914. It shows a great decrease in the amount of ash lumber cut in the Lake States, which was chiefly from virgin supplies of black ash, and a great increase in the supply from the lower Mississippi Valley States,[1] chiefly from green ash, both second and old growth, on intrinsically good agricultural land which will ultimately be cleared for farming. New England, the Middle States, and the Central States, where the supply is chiefly from second-growth white ash on more or less permanent woodlots, are holding their own or increasing in the proportion which they contribute to the ash lumber output.

[1] If the cut of ash for cooperage stock were added to the lumber cut, the lower Mississippi Valley States would be considerably further in the lead.

TABLE 9.—*Proportion of the ash lumber cut in the United States contributed by different regions in different years.*

Region.	1899	1909	1910	1912	1914	1915
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
(1) New England	1.5	5.0	5.5	5.2	5.5	4.5
(2) Middle Atlantic	5.1	8.6	7.4	9.3	10.0	8.3
(3) Lake States (Michigan, Wisconsin, and Minnesota)	38.3	19.2	19.3	13.7	13.8	14.9
(4) Ohio, Indiana, Illinois, West Virginia, Kentucky, and Tennessee	30.8	32.6	32.8	36.9	31.0	31.4
(5) South Atlantic and Alabama	4.9	6.5	5.7	6.9	8.6	8.2
(6) Lower Mississippi Valley, including Missouri, Arkansas, Oklahoma, Texas, Louisiana, and Mississippi	17.9	27.6	28.8	27.3	30.5	32.4
(7) Kansas, Nebraska, Iowa, and South Dakota	.1	.3	.2	.2	.1	.2
(8) Washington, Oregon, and California	1.4	.2	.3	.5	.5	.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

THE SUPPLY OF ASH TIMBER.

About two-thirds of the present supply of ash is second growth, chiefly in small timber tracts and wood lots attached to farms, and about one-third is virgin timber, chiefly in large tracts. Usually it forms less than 5 per cent of the stand in which it grows. Black ash in the Lake States and green ash in the lower Mississippi Valley often form from 20 to 25 per cent of the original stand, but these original supplies are rapidly becoming exhausted and will seldom be reproduced. The green ash, however, is for the most part on agricultural land which ultimately will be drained and used for farming. At the present rate of cutting the supply of virgin ash will be practically exhausted in the next 10 years; but this does not mean that the annual cut will be very greatly diminished in the next decade, as it is already largely dependent on second growth. Furthermore, ash is a tree which, with a little encouragement, will maintain or increase the proportions it forms of second-growth stands on sites where it originally occurred naturally.

Within the geographical range of the three important commercial species—white, green, and black ash—there are approximately 400,000,000 acres of woodland; but not over 4 per cent of this area has even a thin natural stand of ash such as would have an average increase by growth of, say, 10 board feet of ash per acre annually. This indicates that the maximum annual growth of ash to be expected in the United States is 160,000,000 feet, and the probability is that it will be considerably less. With the exhaustion of the virgin ash timber, therefore, it would be well, in order that the supply of ash may be maintained, to reduce the annual cut to something less than 150,000,000 feet, unless intensive forest management of the genus is undertaken on a considerable scale. This does not take into consideration, on the one hand, decrease in area of woodland containing ash by clearing for agriculture, or, on the other, the possible influence of forest management in increasing the per acre growth of ash, factors which might be considered, to some extent at least, as counterbalancing each other.

CHARACTERISTICS OF ASH WOOD.

GENERAL DESCRIPTION OF THE WOOD.

Ash wood is heavy, strong, tough, stiff, and hard and takes a high polish. It shrinks only moderately in seasoning and bends well when seasoned. The layers of annual growth are clearly marked by several rows of large, open ducts occupying (in slow-growing specimens) nearly the entire width of the annual ring. The medullary rays are numerous and obscure. The color of the heartwood is brown; the sapwood is much lighter, often nearly white.

The proportion of heartwood and sapwood varies chiefly with the age of the tree. Old-growth ash trees, over 150 years in age, have a narrow rim of sap, usually less than 2 inches wide, and in black ash often less than 1 inch. (See Pl. VIII.) In second-growth ash less than 100 years in age the width of the sap, on trees over 12 inches in diameter, is usually from 3 to 6 inches, and forms by far the greater part of the lumber cut. Black-ash lumber, which usually is cut from very old, slow-growing trees, is mostly dark-colored heartwood, and the lumber for this reason is known commercially as brown ash. Over half of the white-ash and nearly all of the green-ash lumber is cut from trees less than 100 or 150 years in age and is mostly of the lighter color characteristic of sapwood.

Lumber from rapid-growing second-growth white and green ash is rather coarse grained and not especially attractive in figure. Lumber from slow-growing old growth, especially black ash, is finer grained and handsome in figure. Curly-ash lumber is occasionally cut, usually from black ash, and has an especially handsome figure.

The fuel value of dry-ash wood is, on the average, 81 per cent as high as hickory and 91 per cent as high as oak. Heavy sticks of ash frequently will equal oak in fuel value, especially blue, white, and green ash. In general, a cord of ash wood will give approximately the same heating value as 1 ton of high-grade coal.[1]

STRUCTURE.

Ash is a conspicuously ring-porous wood with numerous pores plainly visible to the naked eye in cross section. The structure, as it appears in transverse, radial, and tangential sections, is shown by Plate IV, figures 1, 2, and 3.[2] The annual ring is made conspicuous

[1] From figures compiled by H. S. Betts and Ernest Bateman, of the Forest Service.
[2] Photomicrographs of slides made by A. Koehler, of the Forest Products Laboratory.

by the contrast of the belt of springwood containing numerous large pores with that of the denser summerwood containing minute pores. The summerwood pores are arranged singly or in broken lines, the course of which is never radial. The pith or medullary rays are very minute and scarcely distinct when viewed in cross section, which is an important distinguishing characteristic of the genus, but one which is also characteristic of osage orange and catalpa, the woods that most closely resemble ash in structure. Osage-orange wood can be distinguished readily by its bright yellow color and by its very great hardness and weight. Catalpa wood, on the other hand, is light and soft and has the pores of its summerwood arranged in clusters, which is not the case in ash or osage orange.

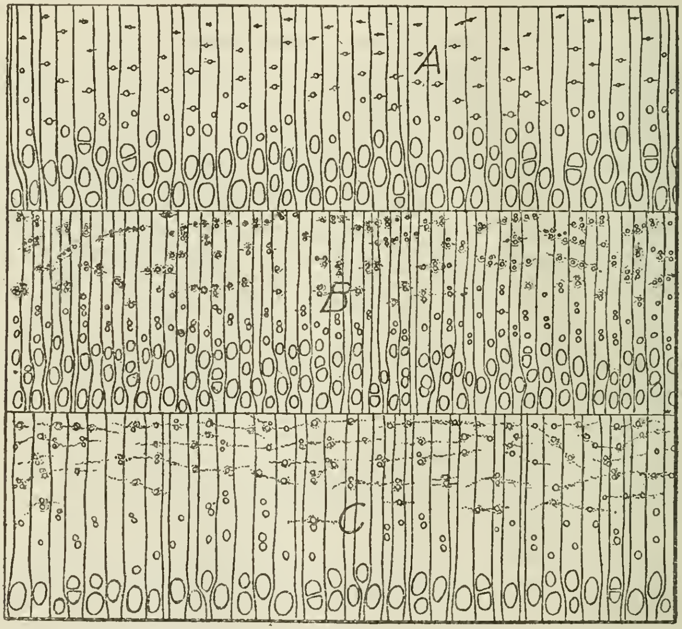


FIG. 3.—Transverse sections of ash wood under small hand lense; *A*, black ash; *B*, white ash; *C*, green ash. Taken from Bulletin 10 of the Division of Forestry (1895), by Prof. Filibert Roth.

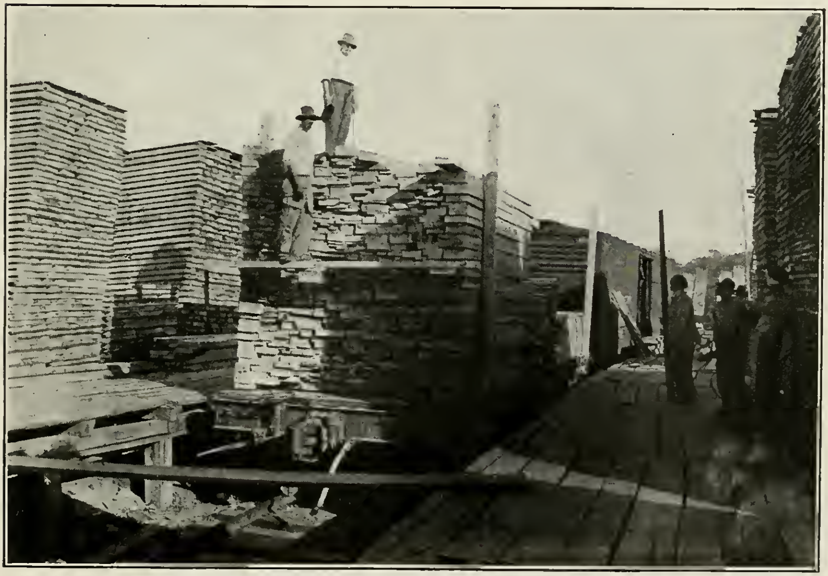
It is difficult and often impossible to distinguish, with any degree of certainty, the wood of the different species of ash. (Pls. V and VI.) Determination of species on the basis of wood characteristics, therefore, is very unsatisfactory. The following points of difference (fig. 3) in the important commercial series, as they appear under the magnifying glass, are taken from Forest Service Bulletin 10, "Timber," by Filibert Roth:[1]

[1] Photomicrographs of slides made by A. Koehler, of the Forest Products Laboratory.

F-25519A

FIG. 1.—WHITE ASH LOGS AT THE MILL. CENTRAL TENNESSEE.

The general run of ash logs are clear and straight but not large.



F-25518A

FIG. 2.—WHITE ASH LUMBER IN YARD AT NASHVILLE, TENN.

Note the predominance of dimension lumber.

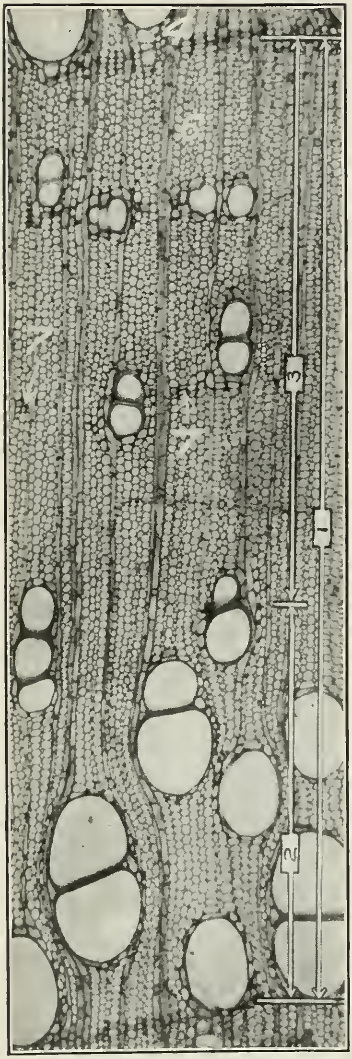


FIG. 1.—Transverse section.

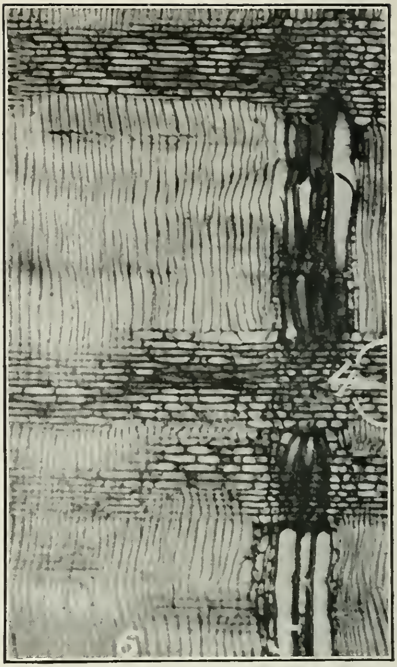


FIG. 2.—Tangential section.

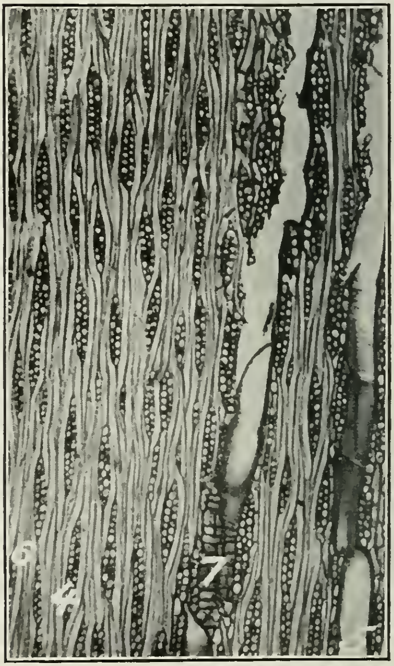
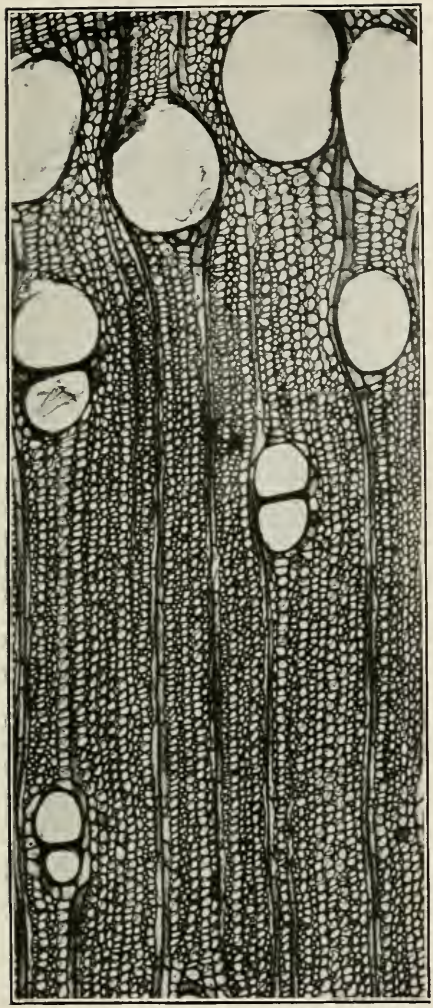


FIG. 3.—Radial section.

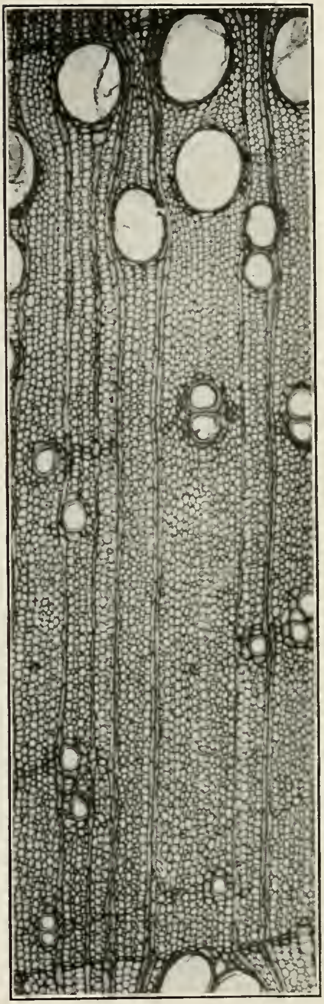
STRUCTURE OF WHITE ASH WOOD MAGNIFIED 50 DIAMETERS.

Numbers on photographs refer to the following: (1) Width of annual ring; (2) width of springwood; (3) width of summerwood; (4) medullary or pith ray; (5) vessel; (6) wood fiber; (7) wood parenchyma.



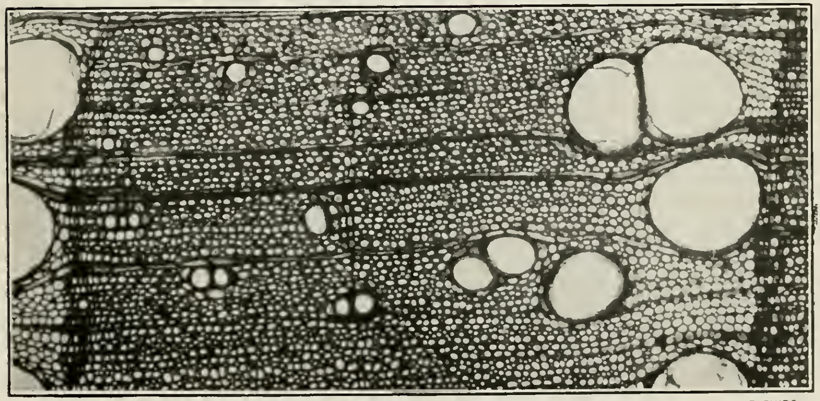
F-5WDS

FIG. 1.—Pumpkin ash (*F. profunda*).



F-6WDS

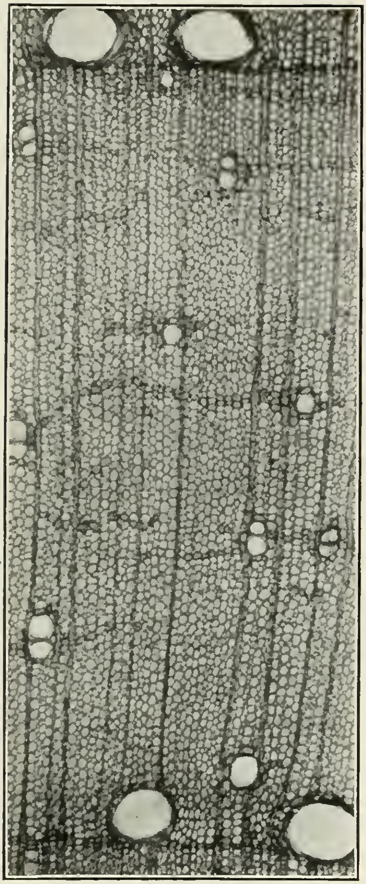
FIG. 2.—Blue ash (*F. quadrangulata*).



F-7WDS

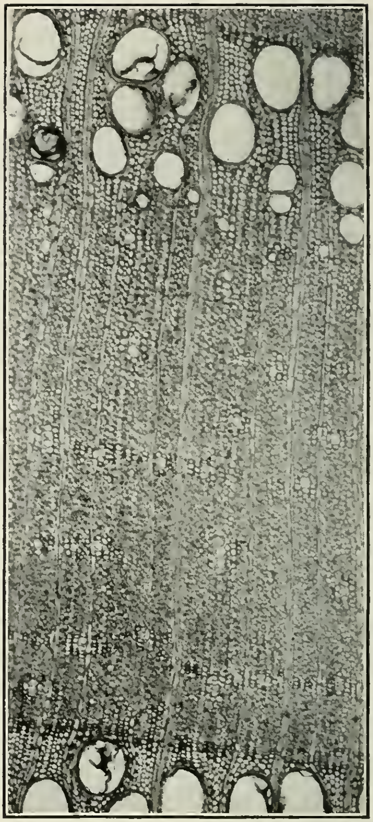
FIG. 3.—Biltmore ash (*F. biltmoreana*).

TRANSVERSE SECTIONS OF ASH WOOD, MAGNIFIED 50 DIAMETERS.



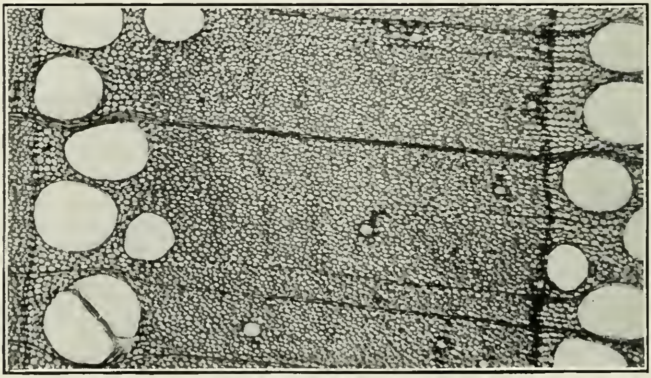
F-8WDS

FIG. 1.—Water ash (*F. caroliniana*).



F-9WDS

FIG. 2.—Blue ash (*F. quadrangulata*).



F-10WDS

FIG. 3.—Black ash (*F. nigra*).

TRANSVERSE SECTIONS OF ASH WOOD, MAGNIFIED 50 DIAMETERS.

1. Pores in the summerwood more or less united in lines.
   a. The lines short and broken, occurring mostly near the limit of the ring .... *White ash*
   b. The lines quite long and conspicuous in most parts of the summerwood .... *Green ash*
2. Pores in the summerwood not united into lines, or rarely so.
   a. Heartwood reddish brown, and very firm .... *Red ash*
   b. Heartwood grayish brown and much more porous .... *Black ash*

MECHANICAL PROPERTIES OF THE DIFFERENT SPECIES.[1]

Table 10 gives the results of a large number of tests to determine the mechanical properties of different species of eastern ash from different parts of the country, and Table 11 gives a summary of them in general terms and in order of the relative strength of the different lots tested. Strength[2] is the most important property and therefore the factors which influence it are considered at length.

Specific gravity or weight.—The ashes follow the general law of timber in regard to the relations of mechanical properties and weight; i. e., all the mechanical properties increase in force as the specific gravity of the wood increases. This is not, however, always a straight line relation.

[1] By J. A. Newlin, of the Forest Products Laboratory.
[2] Bending strength and crushing strength, such as are important in beams and posts.

TABLE 10.—*Average physical and mechanical properties of green or air seasoned ash, based on tests of small clear specimens 2 by 2 in cross-section—bending 28-inch span.*

Species: Common and botanical name.	Locality where grown.	Number of trees.	Tree average.	Rings per inch.	Proportion of sap.	Moisture content.	Specific gravity oven dry. Based on— Volume when tested.	Specific gravity oven dry. Based on— Volume when oven dry.	Shrinkage from green to oven dry condition. In volume.	Shrinkage from green to oven dry condition. Radial.	Shrinkage from green to oven dry condition. Tangential.	Static bending. Fiber stress at elastic limit.	Static bending. Modulus of rupture.	Static bending. Modulus of elasticity.	Static bending. Work in bending. To elastic limit.	Static bending. Work in bending. To maximum load.	Static bending. Work in bending. Total.
GREEN.					*P. ct.*	*P. ct.*			*P. ct.*	*P. ct.*	*P. ct.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Inch lbs. per cu. in.*	*Inch. lbs. per cu. in.*	*Inch lbs. per cu. in.*
Biltmore ash (Fraxinus biltmoreana).	Overton County, Tenn..	5	Average...	16.6	39.7	41.5	0.507	0.584	12.6	4.2	6.9	5,530	9,277	1,335	1.31	11.6	27.1
			Maximum.	17.8	68.2	44.4	.550	.636	13.3	5.2	7.6	6,620	10,670	1,642	1.49	14.9	36.5
			Minimum.	15.1	18.9	37.7	.473	.539	11.5	3.2	6.0	4,520	8,230	1,190	.97	9.6	16.5
Black ash (Fraxinus nigra)..........	Ontonagon County, Mich.	6	Average...	23.1	3.0	90.6	.447	.526	15.2	5.0	7.8	2,610	6,000	1,107	.42	11.3	30.0
			Maximum.	26.7	6.5	101.6	.490	.600	17.3	6.0	8.9	3,790	7,990	1,431	.60	18.2	39.6
			Minimum.	18.5	1.2	75.3	.402	.430	13.9	4.0	6.9	1,840	4,290	798	.24	6.2	16.8
Blue ash (Fraxinus quadrangulata)..	Bourbon County, Ky...	5	Average...	12.5	87.7	39.3	.533	.603	11.7	3.9	6.5	5,700	9,650	1,241	1.47	14.7	40.1
			Maximum	15.5	100.0	41.0	.568	.647	13.2	4.5	7.5	6,640	10,350	1,366	1.79	17.6	46.8
			Minimum.	9.8	72.7	38.2	.480	.536	10.4	3.2	5.6	4,780	8,190	1,091	1.18	10.3	30.9
Green ash (Fraxinus lanceolata).....	Richland Parish, La....	5	Average...	20.6	68.1	47.4	.516	......	......	......	......	4,450	8,880	1,319	.87	10.6	24.0
			Maximum.	24.8	90.2	48.5	.531	......	......	......	......	5,010	9,520	1,459	1.29	12.0	26.6
			Minimum.	15.5	53.3	45.2	.504	......	......	......	......	3,860	8,390	1,127	.65	9.0	20.9
Green ash (Fraxinus lanceolata).....	New Madrid County, Mo.	5	Average...	13.7	57.1	48.3	.534	.631	13.3	4.6	7.1	6,110	10,040	1,480	1.42	13.0	32.7
			Maximum.	20.0	95.7	52.0	.566	.669	14.2	5.0	8.4	6,960	11,120	1,721	1.72	15.9	48.0
			Minimum.	9.4	21.9	42.6	.463	.556	11.9	3.6	5.4	4,380	7,480	1,023	1.07	9.0	13.6
Pumpkin ash (Fraxinus profunda)..	New Madrid County, Mo.	3	Average...	21.0	48.5	51.4	.485	.551	12.0	3.7	6.3	4,470	7,600	1,043	1.08	9.4	18.7
			Maximum.	24.5	50.0	53.8	.523	.600	12.6	4.0	7.5	5,550	8,890	1,263	1.37	12.1	35.6
			Minimum.	17.7	46.0	48.7	.450	.504	11.2	3.2	5.4	3,760	6,590	855	.93	7.5	......
White ash (Fraxinus americana)....	Stone County, Ark......	5	Average...	14.8	61.0	38.2	.550	.640	12.6	4.3	6.4	5,180	9,920	1,416	1.10	20.0	43.7
			Maximum.	17.6	89.2	41.4	.606	.730	15.5	5.9	9.0	6,180	11,850	1,971	1.23	27.3	54.6
			Minimum.	11.4	29.9	36.7	.498	.550	9.6	3.1	4.7	4,490	8,670	1,104	.95	15.6	29.8

White ash (Fraxinus americana).....	Oswego County, N. Y...	5	Average...	8.8	54.8	40.3	.582	.708	14.0	5.3	8.7	6,140	10,760	1,635	1.30	16.3	41.2
			Maximum.	11.4	91.2	42.0	.606	.773	15.0	5.8	9.6	6,890	12,020	1,842	1.46	19.6	51.2
			Minimum.	6.1	23.3	38.8	.526	.677	12.4	4.6	7.4	5,640	9,860	1,398	1.23	13.7	30.5
White ash (Fraxinus americana)....	Pocahontas County, W. Va.	5	Average...	17.2	10.6	48.1	.495	.559	12.6	4.1	6.6	4,600	8,310	1,285	.96	13.6	32.8
			Maximum.	23.1	19.5	52.9	.528	.588	14.2	4.8	7.6	5,340	9,120	1,407	1.15	16.7	44.6
			Minimum.	11.4	00.0	43.5	.460	.530	11.0	3.4	5.7	4,060	7,130	1,074	.83	10.8	18.4
AIR SEASONED.																	
Biltmore ash (Fraxinus biltmoreana).	Overton County, Tenn..	....	Average...	16.6	39.7	5.4	.586	......	......	......	......	12,110	15,560	1,760	4.60	11.7	13.4
Black ash (Fraxinus nigra)..........	Ontonagon County, Mich.	....	Average...	23.1	3.0	9.1	.500	......	......	......	......	10,340	16,130	1,975	2.05	17.9	38.6
Blue ash (Fraxinus quadrangulata)..	Bourbon County, Ky...	....	Average...	12.5	87.7	9.6	.575	......	......	......	......	8,720	14,770	1,433	3.00	14.3	33.7
Green ash (Fraxinus lanceolata).....	Richland Parish, La....	....	Average...	20.6	68.1	11.2	.552	......	......	......	......	8,950	13,680	1,615	2.82	12.6	21.5
Green ash (Fraxinus lanceolata).....	New Madrid County, Mo.	....	Average...	13.7	57.1	9.6	.588	......	......	......	......	9,970	16,110	1,768	3.18	14.6	21.9
Pumpkin ash (Fraxinus profunda)..	New Madrid County, Mo.	....	Average...	21.0	48.5	9.6	.514	......	......	......	......	6,980	11,810	1,312	2.11	7.8	12.5
White ash (Fraxinus americana)....	Stone County, Ark.......	....	Average...	14.8	61.0	10.5	.609	......	......	......	......	10,770	17,650	1,942	3.42	14.8	36.2
White ash (Fraxinus americana)....	Oswego County, N. Y...	....	Average...	8.8	54.8	9.5	.637	......	......	......	......	13,010	18,650	1,985	4.80	17.0	25.9
White ash (Fraxinus americana)....	Pocahontas County, W. Va.	....	Average...	17.2	10.6	6.9	.554	......	......	......	......	9,580	15,960	1,684	3.16	13.4	26.2

TABLE 10.—*Average physical and mechanical properties of green or air seasoned ash, based on tests of small clear specimens 2 by 2 in cross-section—bending 28-inch span*—Continued.

Species: Common and botanical name.	Locality where grown.	Number of trees.	Tree average.	Impact bending.				Compression parallel to grain.			Compression perpendicular to grain.	Hardness. Load required to imbed a 0.444-inch ball to one-half its diameter.			Shearing strength parallel to grain.		Cleavage strenght per inch of width.		Tension perpendicular to grain.	
															When surface of failure is—					
				Fiber stress at elastic limit.	Modulus of elasticity.	Work in bending to elastic limit.	Height of drop causing complete failure—50-pound hammer.	Fiber stress at elastic limit.	Crushing strength.	Modulus of elasticity.	Fiber stress at elastic limit.	End surface.	Radial surface.	Tangential surface.	Radial.	Tangential.	Radial.	Tangential.	Radial.	Tangential.
GREEN.				*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Inch lbs. per cu. in.*	*Ins.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs.*	*Lbs.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Biltmore ash (Fraxinus biltmoreana).	Overton County, Tenn.	5	Average...	11,930	1,657	4.9	30	3,560	3,980	1,488	875	953	838	868	1,260	1,205	333	353	507	564
			Maximum.	15,590	1,974	6.8	41	4,420	4,870	1,731	980	1,060	961	1,064	1,482	1,538	394	525	554	673
			Minimum.	10,290	1,427	4.2	20	2,900	3,270	1,298	715	781	662	691	1,072	1,005	300	273	443	480
Black ash (Fraxinus nigra).	Ontonagon County, Mich.	6	Average...	7,230	1,182	2.5	35	1,620	2,340	1,120	409	610	546	559	884	849	307	225	519	461
			Maximum.	8,960	1,558	2.9	56	2,430	3,080	1,462	456	741	696	660	956	1,030	327	255	569	562
			Minimum.	5,650	979	1.9	24	1,060	1,730	830	341	501	447	448	770	734	275	183	464	383
Blue ash (Fraxinus quadrangulata).	Bourbon County, Ky.	5	Average...	11,140	1,394	5.0	43	3,540	4,180	1,308	994	1,140	1,013	1,043	1,558	1,529	308	398	507	660
			Maximum.	12,730	1,489	6.1	58	3,810	4,490	1,602	1,195	1,288	1,232	1,247	1,785	1,850	361	451	680	764
			Minimum.	10,010	1,271	4.0	29	3,100	3,600	1,000	840	983	775	822	1,375	1,303	259	360	395	478
Green ash (Franxius lanceolata).	Richland Parish, La.	5	Average...	11,720	1,388	5.6	32	3,210	4,040	1,497	801	842	729	734	1,239	1,166	357	341	616	611
			Maximum.	12,020	1,506	5.9	39	3,700	4,160	1,700	868	889	780	894	1,361	1,258	390	424	837	721
			Minimum.	11,250	1,186	5.2	28	2,810	3,880	1,262	740	779	651	645	1,153	1,090	284	244	475	427
Green ash (Fraxinus lanceolata).	New Madrid County, Mo.	5	Average...	11,150	1,571	4.4	37	3,920	4,360	1,545	1,012	1,073	977	1,037	1,332	1,305	329	361	553	574
			Maximum.	12,290	1,833	5.0	44	4,380	4,710	1,799	1,101	1,211	1,132	1,279	1,433	1,416	352	430	606	623
			Minimum.	7,720	944	3.5	22	2,890	3,300	1,204	937	880	750	757	1,204	1,164	280	328	493	483

Pumpkin ash (Fraxinus profunda).	New Madrid County, Mo.	3	Average...	8,760	1,204	3.7	31	2,830	3,360	1,098	989	885	772	733	1,229	1,199	337	377	587	561
			Maximum.	10,720	1,438	4.6	42	3,580	3,950	1,391	1,155	1,007	985	955	1,356	1,288	359	428	643	766
			Minimum.	7,590	972	2.7	24	2,360	2,940	864	851	798	632	578	1,117	1,089	302	334	521	416
White ash (Fraxinus americana).	Stone County, Ark.	5	Average...	11,710	1,564	4.9	33	3,510	4,220	1,531	889	1,121	1,000	1,017	1,360	1,312	333	346	645	671
			Maximum.	15,280	2,095	6.2	47	4,240	5,120	2,410	943	1,262	1,212	1,262	1,471	1,430	408	384	738	792
			Minimum.	8,480	1,116	3.6	19	2,880	3,720	1,115	800	919	784	750	1,139	1,184	254	291	520	619
White ash (Fraxinus americana).	Oswego County, N. Y.	5	Average...	13,780	1,784	5.9	47	3,820	4,630	1,720	794	1,145	1,088	1,078	1,600	1,609	392	488	697	877
			Maximum.	15,700	2,110	6.6	54	4,500	5,170	2,040	988	1,179	1,194	1,195	1,732	1,770	429	535	866	955
			Minimum.	10,840	1,436	4.6	36	3,150	3,960	1,437	559	1,110	935	995	1,403	1,393	344	440	505	772
White ash (Fraxinus americana).	Pocahontas County, W. Va.	5	Average...	11,620	1,490	5.1	38	2,950	3,390	1,465	705	872	789	781	1,204	1,162	303	368	546	634
			Maximum.	12,390	1,696	6.0	46	3,510	3,710	1,747	810	948	892	927	1,289	1,243	336	424	748	702
			Minimum.	10,080	1,284	4.4	32	2,390	2,950	1,029	611	790	685	644	1,076	1,043	269	340	440	546
AIR SEASONED.																				
Biltmore ash (Fraxinus biltmoreana).	Overton County, Tenn.	....	Average ..	19,850	2,150	10.4	46	7,140	10,370	2,045	2,020	2,060	1,395	1,265	2,120	1,825	449	456	864	762
Black ash (Fraxinus nigra).	Ontonagan County, Mich.	....	Average...	....	2,276	......	44	6,300	8,190	2,015	1,270	1,398	897	1,090	1,997	1,592	366	428	585	935
Blue ash (Fraxinus quadrangulata).	Bourbon County, Ky.	....	Average...	20,550	2,245	10.5	42	6,120	7,735	1,394	1,911	1,893	1,374	1,338	1 990	2,316	404	505	467	......
Green ash (Fraxinus lanceolata).	Richland Parish, La.	....	Average...	15,850	1,910	7.3	32	4,750	7,300	1,825	1,292	1,676	1,196	1,110	1,910	1,755	314	425	755	616
Green ash (Fraxinus lanceolata).	New Madrid County, Mo.	....	Average...	18,900	2,210	9.0	30	5,910	7,850	2,133	2,220	1,870	1,428	1,296	2,361	2,312	582	545	786	693
Pumpkin ash (Fraxinus profunda).	New Madrid County, Mo.	....	Average...	15,150	1,697	7.9	22	4,035	6,340	1,185	1,995	1,535	1,031	1,021	2,028	1,758	514	404	1,020	636
White ash (Fraxinus americana).	Stone County, Ark.	....	Average...	14,920	1,930	6.5	34	6,110	7,900	1,870	1,315	2,065	1,486	1,345	2,300	2,130	680	496	1,055	682
White ash (Fraxinus americana).	Oswego County, N. Y.	....	Average...	23,840	2,490	12.8	46	8,530	9,260	2,080	2,090	2,240	1,568	1,792	2,540	2,510	506	436	1,255	1,000
White ash (Fraxinus americana).	Pocahontas County, W. Va.	....	Average...	19,050	1,932	11.0	37	5,140	8,480	1,940	1,762	1,833	1,208	1,240	2,215	1,802	391	228	945	849

TABLE 11.—*Physical and mechanical properties of ash of different species from different localities.*

[Expressed in general terms [1] for comparison with other species, and in numbers denoting their relative values for comparison with each other, giving white ash from New York the value of 100 as a standard, together with description of sites from which the materials tested were secured.]

Species and locality.	Weight.	Strength as a beam or post.	Hardness.	Shock-resisting ability.	Stiffness.	Shrinkage.	Rings per inch of test pieces.	Number and age of trees from which test pieces were taken.
White ash, New York (fresh to moist upland, sandy loam, elevation 300 feet).	Heavy (100)	Very strong (100).	Hard (100)	Excellent (100).	Stiff (100)	Moderate (100).	6.1 to 11.4, average 8.8.	5 trees, 50 to 68 years, average 60 years.
White ash, Arkansas (limestone upland, fresh to moist, Ozark Hills, far to the west of the best region of the species' occurrence).	Heavy (94)	Strong (89)	Hard (93)	Good (95)	Stiff (91)	Very moderate (90).	11.4 to 17.6, average 14.8.	5 trees, 90 to 122 years, average 104 years.
Green ash, Missouri (rich overflow bottom land, dry during growing season).	Heavy (91.8)	Strong (89)	Hard (100)	Good (79)	Stiff (92)	Very moderate (95).	9.4 to 20, average 13.7.	5 trees, 90 to 210 years, average 140 years.
Blue ash, Kentucky (limestone blue grass hills, from open pastured forest, which should produce unusually tough, strong wood).	Heavy (91.6)	Strong (95)	Hard (99)	Good (92)	Moderately stiff (78).	Very moderate (84).	9.8 to 15.5, average 12.5.	5 trees, 150 to 190 years, average 170 years.
Green ash, Louisiana (bottom land too wet for best growth until comparatively recently).	Heavy (89)	Strong (81)	Hard (78)	Moderately good (67).	Moderately stiff (84).	....	15.5 to 24.8, average 20.6.	5 trees, 125 to 193 years, average 171 years.
Biltmore ash, Tennessee (Upland, fresh to dry stony loam, limestone rock underlying; dense forest).	Heavy (87)	Strong (84)	Hard (85)	Good (69)	Stiff (87)	Very moderate (90).	15.1 to 17.8, average 16.6.	5 trees, 150 to 220 years, average 188 years.
Oregon ash, Oregon (rich alluvial sandy mountain valley soil; dense forest).	Heavy	....	....	....	....	....	9.9 to 15.6, average 12.4.	3 trees, 105 to 135 years, average 123 years.
White ash, West Virginia (steep north slopes 3,500 feet elevation, thin, moist, clay loams).	Moderately heavy (85).	Moderately strong (75).	Hard (76)	Good (82)	Moderately stiff (83).	Very moderate (90).	11.4 to 23.1, average 17.2.	5 trees, 160 to 300 years, average 200 years.
Pumpkin ash, Missouri (bottom land, wet and swampy land till comparatively recently).	Moderately heavy (83).	Moderately strong (67).	Hard (86)	Moderately good (56).	Moderately limber (66).	Moderately small (86).	17.7 to 24.5, average 21.	3 trees, 180 to 230 years, average 210 years.
Black ash, Michigan (cold, wet, swampy land, short growing season, and slow growth).	Moderately heavy (77).	Moderately weak (62).	Moderately hard (54).	Good (79)	Moderately stiff (76).	Moderate (109).	18.5 to 26.7, average 23.1.	6 trees, 170 to 230 years, average 210 years.

[1] See key for classification of terms used in describing physical and mechanical properties of woods grown in the United States in the Appendix, pp. 49 to 52.

Rate of growth.—Generally speaking, rapid-growing ash trees produce better timber than slow-growing trees; the more rapid the growth the greater the density and the better the quality of the timber.[1] Nevertheless, perfectly thrifty trees grown under widely varying conditions, especially of moisture, will probably show a large difference in rate of growth, with practically no difference in density or mechanical properties. This is known to be true of other species, but data determined are not sufficient to verify it with regard to the ashes.

Position in tree.—The toughest material appears to be at the butt, and the material strongest as a beam or upright is found higher in the tree. As to position in cross section, the timber of best quality appears to be from 3 to 7 inches from the center of the tree, the quality gradually becoming poorer as the distance from the center increases. Suppressed or slow growth in early life, followed by rapid growth in later life, may upset this relation, and the best material may be found in the outer portion of an old tree. The value of the timber in any portion of the cross section depends on its specific gravity.

Age.—Since the mechanical powers show a gradual decrease in the wood outside of 7 inches from the center, old trees (or those of large diameter) would average weaker than the younger trees. However, this is by no means an infallible rule. An ash tree of any age which is perfectly healthy and not suppressed is probably putting on wood of high mechanical value. Any circumstances causing the vigor of the tree to decrease would probably cause it to put on inferior wood.

Heart and sap.—The results of tests fail to show that any difference is caused in the mechanical properties by a change from sap to heart. In most mature trees the heartwood is stronger, tougher, and has better shock-resisting ability than the sapwood. On the other hand, in young trees with a very small proportion of heart, the reverse is normally true. The density of the wood is the criterion which indicates which is the better in any particular instance. In trees of equal age and of the same rate of growth but having widely different proportions of sap, those with the larger proportion of sap were not found to be superior to those containing less sap. The data show without doubt that the grading should be on the basis of density and that the percentage of sap should be ignored entirely.

Locality.—It is probably immaterial in what section of country the timber is grown. The thing to be sought is dense, strong wood. This is best obtained from rapid-growing, comparatively young, small to

[1] Rapid growth, however, is not the reason for better quality, but rather it is the general vigor of the tree which results in density of wood as well as rapidity of growth.

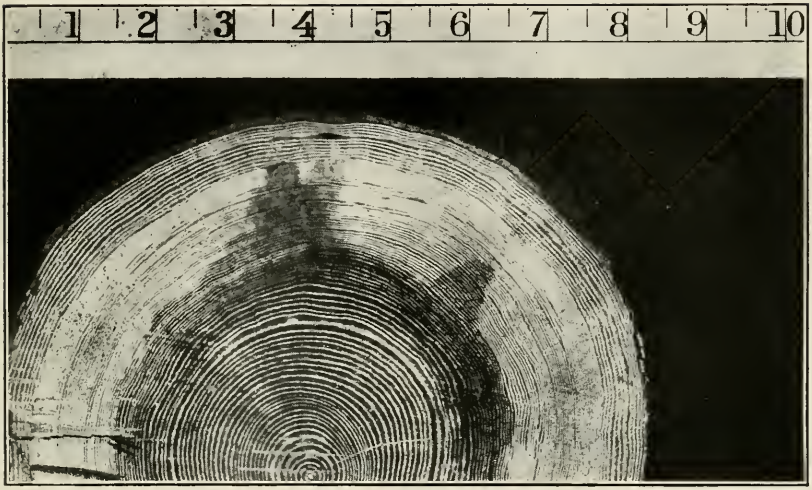
medium sized trees. The silvicultural conditions for growing such trees are a good soil and abundant growing space.

Species.—Table 10 indicates that distinction between species is of little importance in judging mechanical values. Thus while one lot of white ash was the best of any tested, two other lots ranked below one of green ash.

With the exception of black ash, which will be considered later, the differences in mechanical properties of the various species of ash are the same as would be expected in trees of the same species with varying specific gravities. In general, however, ash species growing under natural conditions will rank about as follows in relative strength as a beam or post: White ash, green ash, blue ash, Biltmore ash, pumpkin ash, black ash. Pumpkin ash and black ash usually are found growing under unfavorable conditions (wet swamps and slow growth) for putting on dense wood; while white, blue, and Biltmore ash occur naturally on more favorable sites; green ash occurs about half on sites with defective drainage and half on sites where the drainage is sufficient, but always on rich alluvial soil. (See Pls. VII, VIII, and IX.)

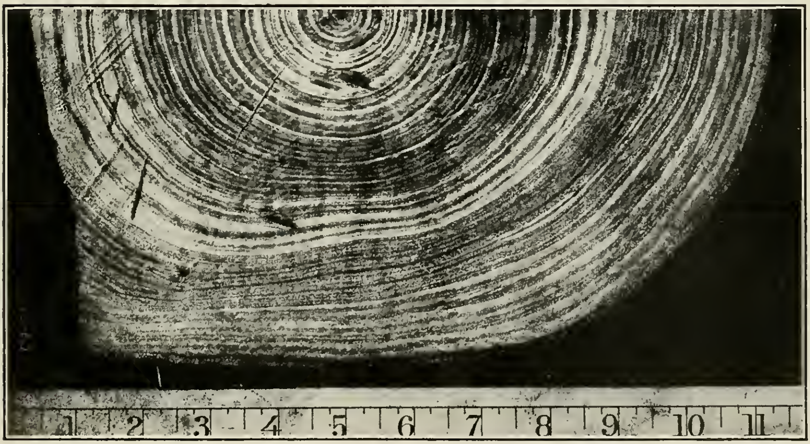
A further classification of the relative strength of the different species, of importance to future growers of ash timber, may be made on the basis of uniformly fast growing, small to medium sized trees, growing under favorable conditions, such as would be secured under proper management. From this standpoint the species probably would rank as follows: White ash, green ash, Biltmore ash, blue ash, and black ash. It would be hard to say whether pumpkin ash would precede or follow blue ash, where grown under favorable conditions. This ranking of species is based on Table 10, consideration being given at the same time to rate of growth (rings per inch), age (or size), character of site, and the conditions given in Table 11. These factors account for apparent variations in the relative strength of the different species. Thus the blue ash in the table has a relatively high rank because of the unusually favorable conditions for putting on dense wood under which the specimen trees grew—all the trees were predominant and grew in an open stand on limestone soil. It will be seen, also, that the blue ash falls below green ash of Missouri in strength, although equalling it in weight and having fewer rings per inch. Black ash, on the other hand, if grown under favorable conditions, might reasonably be expected to produce much stronger timber than the table indicates—nearly equal to blue ash, to which it is botanically closely related.

The tests on black ash in the green condition indicated almost double as much moisture content as the tests on any of the other ashes. Black ash is the lightest of the ashes tested, is very weak,



F-95257

FIG. 1.—DISK FROM A SUPPRESSED WHITE ASH, 85 YEARS OLD, THE LUMBER FROM WHICH WOULD NOT BE VERY STRONG. CENTRAL NEW YORK.



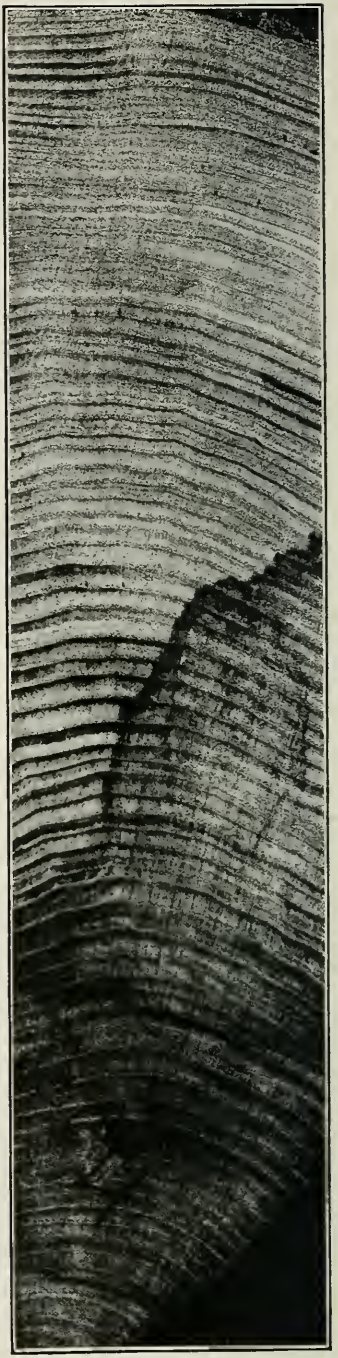
F-95260

FIG. 2.—GREEN ASH, 50 YEARS OLD, FROM ROANOKE RIVER, N. C.

Fairly rapid growth and strong wood.

F-95258

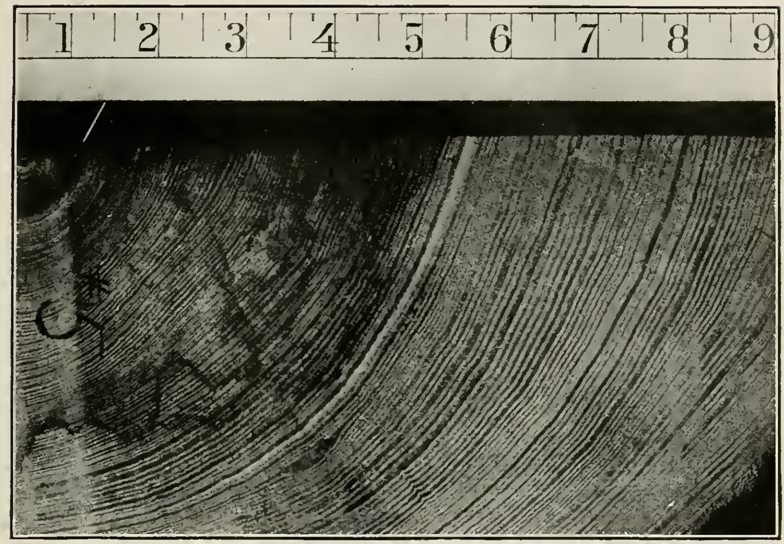
FIG. 1.—Black ash, 220 years old, from northern Michigan. Nearly all heartwood. Tree 24 inches in diameter breasthigh.



F-95259

FIG. 2.—Green ash, 90 years old, the same size as the black ash in figure 1. From southeastern Missouri. Mostly sapwood. Much stronger than the black ash.

DISKS SHOWING MAXIMUM RATE OF GROWTH OF BLACK AND GREEN ASH, AND PROPORTION OF HEARTWOOD AND SAPWOOD.



F-92256

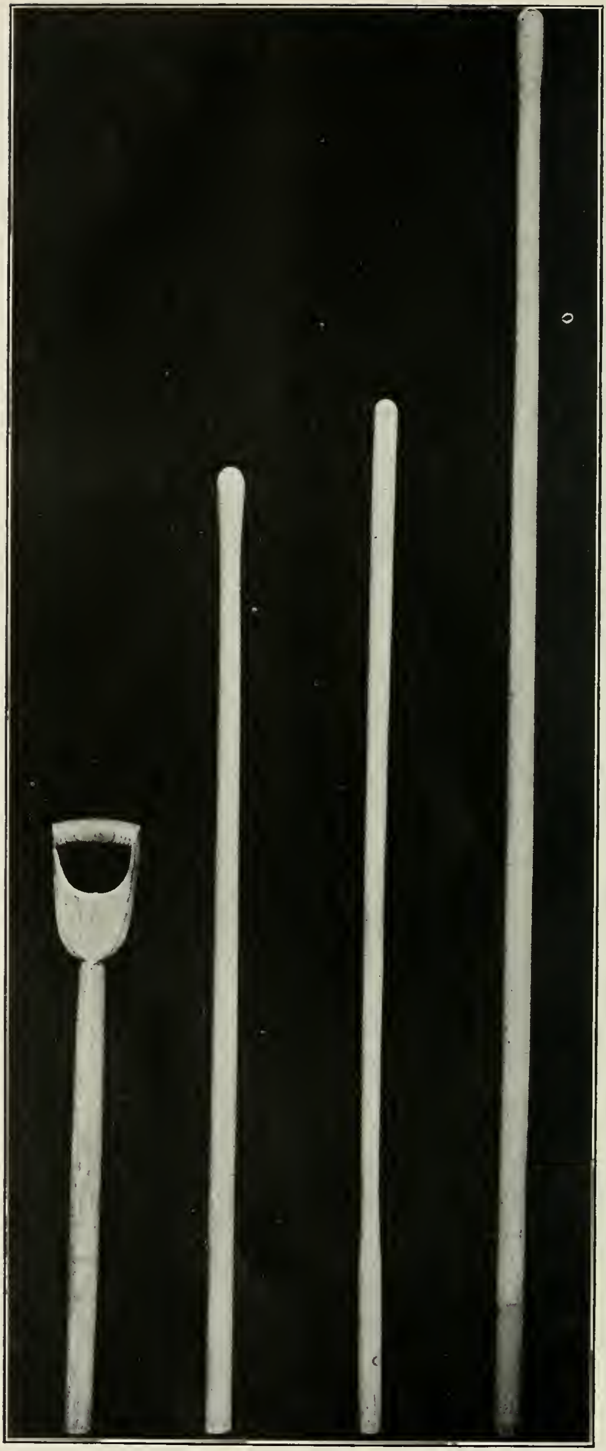
FIG. 1.—DISK FROM 185-YEAR-OLD PUMPKIN ASH FROM SOUTHEASTERN MISSOURI.

Slow growth and not strong for ash.

F-95255

FIG. 2.—DISK FROM 200-YEAR-OLD BLACK ASH FROM NORTHERN MICHIGAN.

Very slow growth and weak wood for ash.



GOOD QUALITY STRAIGHT-GRAINED ASH HANDLES OF THE KIND CHIEFLY MADE FROM ASH.

From left to right: Shovel, fork, hoe, and hayfork handles.

especially in the green condition, and is much the toughest. It showed a remarkable gain in crushing and bending strength as a result of seasoning, and in shock-resisting ability ranks well with the denser species. With but few exceptions, the shrinkage of timber varies directly with the specific gravity. Black ash is one of these exceptions. It has about the same shrinkage as the best grade of white ash, about 25 per cent greater than would be expected for a species of equal specific gravity. For making baskets, hoops, and the like, the peculiar properties of black ash make it rank first among the ashes.

SEASONING.

Ash lumber seasons rapidly, in this respect ranking about as follows with the other common woods, commencing with the most rapid: Red spruce, white ash, red gum, yellow birch, sugar maple, walnut, white oak. This matter of the rate of seasoning is important in connection with rate of increase or decrease in size of lumber when exposed to change in atmospheric conditions, as it is reasonable to assume that those woods which dry most readily are the ones which respond most quickly to the effects of varying conditions, which is not a desirable quality in wood.

In shrinkage from green to oven-dry condition. white ash compares as follows with other species:

	In volume.	Radially.	Tangentially.
	Per cent.	*Per cent.*	*Per cent.*
Ash (white)	13.1	4.8	7.2
Birch (yellow)	16.8	7.4	9.0
Cherry (black)	11.5	3.7	7.1
Gum (red)	16.9	5.3	11.4
Maple (sugar)	14.5	4.8	9.2
Oak (white)	15.8	5.4	9.0
Spruce (red)	11.8	3.8	7.8
Walnut (black)	11.3	5.2	7.1

In a properly operated kiln, ash can be very easily kiln-dried from the green condition with even less checking than would occur in preliminary air seasoning; and for most uses ash is ultimately kiln-dried. It is doubtful whether kiln-dried ash stock would work (shrink and swell) more with changes of atmospheric conditions than that which has been air-dried and then kiln-dried.

CHEMICAL PROPERTIES.

Ash wood consists of a skeleton of cellulose, permeated with a mixture of other organic substances common to hardwoods. "One hundred pounds of wood as sold in the wood yards contains in round numbers 25 pounds of water, 74 pounds of wood, and 1 pound of ashes. The 74 pounds of wood are composed of 37 pounds of carbon (charcoal), 4.4 pounds of hydrogen, and 32 pounds of oxygen."[1]

DURABILITY IN CONTACT WITH THE GROUND.

Ash wood is only moderately durable in contact with the ground. It is used to a minor extent for posts, rails, and gate bars in localities where better timber is not available. White and green ash are as durable as red oak, butternut, and red elm: while black ash is considerably more so because of its large per cent of heartwood, which is due to slow growth. White and green ash are more durable than aspen, basswood, box elder, cottonwood, hard and soft maples, hickory, white elm, and willow, and are preferable to these trees for untreated fence posts. Fence posts from these two ashes will last from 6 to 12 years, depending on size, percentage of heartwood, method of seasoning, the character of the site in which the post is set, and the season of the year when the tree is cut. Black ash posts will usually last from 12 to 15 years.

DISEASES AND INSECTS WHICH ATTACK ASH TIMBER.

Standing ash timber is not subject to extensive damage by disease. Although a number of diseases have been found on the different species of ash, only one has done much serious harm, white rot. Diseased trees are mostly those whose vitality has been weakened by old age, fire, or generally adverse conditions.

White rot occurs in the heartwood of the trunk and main branches, and is caused by the fungus *Polyporus fraxinophilus*, which turns the wood into a mass of yellow pulp. This disease is common in overmature green ash in the lower Ohio Valley and in the Mississippi River bottoms, near their confluence; it is also common on white ash near the western limit of its range in Iowa, Missouri, Kansas, and Oklahoma, where it occurs on dry limestone hills and where 90 per cent of the trees are infected.[2]

The two insects which are of primary importance in connection with ash products are: (1) the ash wood borer (*Neoclytus capraea*) which attacks the logs and bolts from trees felled in the late fall, winter, and early spring, and destroys the sapwood; and, (2) the Lyctus powder post beetle which attacks the sapwood of products after they have been seasoned for a year or more. The Bureau of Entomology, U. S. Department of Agriculture, Washington, D. C., has made special studies of these insects and has discovered practical

[1] From Bulletin 10 of the Division of Forestry, Department of Agriculture, "Timber: Elementary Discussion of Characteristics and Properties of Wood," by Filibert Roth.

[2] Full discussion of this disease is contained in Bulletin No. 32 of the Bureau of Plant Industry, "A Disease of the White Ash Caused by *Polyporus fraxinophilus*.

methods of preventing losses from them through proper handling of logs and lumber. In addition to its publications on the subject, the Bureau of Entomology will supply information by correspondence when special cases are reported to it.

UTILIZATION BY INDUSTRIES.

Practically all of the cut of ash lumber, as given in the United States census reports, is consumed in different wood-using industries. The high value and the scarcity of the wood preclude the use of ash lumber in general construction work.

The uses to which ash is put may be conveniently grouped by the industries. This is done in Table 12, which indicates for each industry the amount of ash material and the proportion of the total that is used, the average price paid for material delivered at the factory, and the total cost of material. In round numbers, 22 per cent of the ash used in industries goes into handles; 20 per cent into butter-tub staves and headings; 15 per cent into vehicles, including automobiles; 7 per cent into planing-mill products; 6 per cent each into refrigerators and kitchen cabinets, furniture (including chairs and chair stock), and car construction; 3 per cent into boxes and crates, agricultural implements, and ships and boats (chiefly oars); 1 per cent each into sporting and athletic goods, fixtures, musical instruments, woodenware and novelties, and hames: and from one-quarter to one-half of 1 per cent into machine construction, pumps, sucker rods, toys, and tanks. A total of about 1 per cent of the ash used goes into plumbers' woodwork, trunks, pulleys and conveyors, picker sticks, printing materials, picture frames and molding, and carpet sweepers. The remainder, comprising less than one-half of 1 per cent, goes into playground equipment, rollers for shades and maps, elevators, professional and scientific instruments, laundry appliances, machinery and electrical apparatus, mine equipment, brushes, patterns and flasks (for foundry work), whips, canes, umbrella sticks, dowels, caskets and coffins, butcher's blocks, aeroplane frames and propellers, weighing apparatus, and gates and fencing.

TABLE 12.—*Use of ash by secondary wood-using industries in the United States.*

Use.	Quantity used annually.		Average cost per 1,000 feet.	Total cost f. o. b. factory.
	Feet b. m.	Per cent.		
(1) Handles	64,156,872	21.72	$29.88	$1,917,033.40
(2) Dairy supplies (chiefly butter tub staves and heading)	60,285,800	20.40	25.43	1,532,876.00
(3) Vehicles and vehicle parts	43,974,668	14.88	42.77	1,880,588.30
(4) Planing-mill products, sash, doors, and blinds, and general mill work	21,304,374	7.21	31.39	668,716.25
(5) Refrigerators and kitchen cabinets	19,066,380	6.45	29.41	560,812.31
(6) Car construction	18,163,433	6.15	49.83	905,158.00
(7) Furniture	15,668,588	5.30	27.21	426,270.56
(8) Agricultural implements	10,677,400	3.61	40.05	427,638.00
(9) Boxes and crates	10,507,308	3.56	14.40	151,257.53
(10) Ship and boat building (chiefly boat oars)	7,985,554	2.70	29.26	233,621.41
(11) Sporting and athletic goods	3,180,000	1.08	34.68	110,293.00
(12) Fixtures	2,783,822	.94	37.16	103,446.00
(13) Chairs and chair stock	2,765,050	.94	27.19	75,190.50
(14) Instruments, musical	2,377,332	.81	53.17	126,399.00
(15) Woodenware and novelties	2,350,000	.80	28.83	67,750.50
(16) Saddles and harness (chiefly harness)	2,103,000	.71	35.18	73,992.00
(17) Machine construction	1,404,362	.48	44.34	62,262.66
(18) Pumps (mostly sucker rods)	975,500	.33	19.41	18,935.00
(19) Toys	895,300	.30	33.22	29,740.00
(20) Tanks	866,000	.29	32.56	28,194.00
(21) Plumbers' woodwork	536,000	.18	24.99	13,395.00
(22) Trunks	534,435	.18	34.66	18,521.00
(23) Pulleys and conveyors	512,100	.17	28.79	14,745.00
(24) Picker sticks and bobbins	437,000	.15	26.66	11,650.00
(25) Printing material	391,000	.13	23.17	9,061.00
(26) Frames and molding, picture	281,815	.10	37.13	10,464.00
(27) Carpet sweepers (probably for handles)	236,394	.08	16.10	3,816.00
(28) Equipment, playground	180,000	.06	31.19	5,615.00
(29) Rollers, shade and map	161,150	.06	22.81	3,676.00
(30) Elevators	145,700	.05	68.68	10,007.00
(31) Instruments, professional and scientific (including litters)	123,600	.04	61.93	7,654.00
(32) Laundry appliances	111,500	.04	23.68	2,640.00
(33) Machinery and apparatus, electric	87,000	.03	49.20	4,280.00
(34) Mine equipment	43,425	.01	22.01	956.00
(35) Brushes	36,400	.01	41.54	1,512.00
(36) Patterns and flasks	35,000	.01	37.86	1,325.00
(37) Whips, canes, and umbrella sticks	30,000	.01	60.00	1,800.00
(38) Dowels	29,000	.01	25.34	735.00
(39) Caskets and coffins	20,000	.01	54.00	1,080.00
(40) Butchers' blocks and skewers	20,000	.01	60.00	1,200.00
(41) Aeroplanes	12,000	[1]	64.67	776.00
(42) Weighing apparatus	5,900	[1]	39.66	234.00
(43) Gates and fencing	700	[1]	18.57	13.00
Total	295,461,482	100.00	32.24	9,525,329.42

[1] Less than one one-hundredth of 1 per cent.

HANDLES.

Certain classes of handles are almost exclusively made out of ash, such as "D" handles for spades and shovels of all kinds and long handles for forks, hoes, rakes, and long shovels. Ash is also used somewhat for handles for cant hooks and grubbing hoes. Odds and ends are often used for small tool, whip, broom, ax and pickax, carpet, and vacuum sweeper handles. It is practically the only wood used for snaths for scythes and cradles. The qualities which make ash especially suitable for handles are straightness of grain, a high degree of stiffness and strength perpendicular to the grain, suitable weight and hardness, and capacity to wear smooth in use. Rapid-growing second-growth white and green ash, which yield the strongest and stiffest wood, are the best and the most often used.

Old-growth ash is usually considered too fine-grained and brittle. Sixty per cent of the timber for handles comes from Ohio, Indiana, and Arkansas. (See Pls. I and X.)

Handle stock usually is sawed out directly from the log in order to have the grain straight, and as a rule can not be made from lumber sawed for general purposes. The price of ash stumpage for handles is from \$5 to \$35 per 1,000 board feet, according to its location and quality, the average being about \$15. The cost of the raw material, delivered at the factory, is from \$25 to \$50 (the average is \$30) per 1,000 board feet in logs and in sawed squares.

In Maine some D-handle factories purchase ash in the form of rived billets or blanks,[1] for which they pay an average of 85 cents per dozen delivered at the railroad. It is possible for a workman to split out about 40 dozen handles per 1,000 board feet of bolts, at a cost of about \$10 for cutting and riving, and worth about \$34 delivered at the railroad. The hauling and freight charges on blanks are, of course, much less than on logs or bolts, and often make it profitable to get them out in this form where it would not pay in bolt form on account of the distance from the market.

DAIRY SUPPLIES.

Practically all of the ash used for dairy supplies goes into butter-tub staves and heading, and covers and hoops for butter churns; a small amount is used for ladles, packers, and butterworkers. Butter tubs are almost always made of ash. It is especially suitable for this purpose because there is nothing in the wood to give butter a disagreeable flavor and because it is very readily worked up into the forms of material used in making the tubs. Slightly more than 50 per cent of the ash manufactured into dairy supplies is used in Illinois, and 28½ per cent in Iowa. The cost of the raw material (manufactured staves, heading, and hoops) amounts to from \$10 to \$33 per 1,000 board feet delivered at the factory. The average is about \$25.

Most of the ash butter-tub material is Mississippi Valley green ash. The hoops, however, are made almost entirely from the black ash of the Lake States. There is practically no difference in the relative desirability of the different species of ash for butter tubs.

The ash butter-tub stave and heading industry utilizes chiefly short lengths cut from small, crooked trees, but only clear material. Knotty stuff can be used for No. 2 staves and heading in lime and other kinds of slack barrels. Logs too crooked to make lumber or long handles can be readily cut up into short bolts 32 inches long and used for making staves and heading. Ash staves are manufactured

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[1] Information supplied by G. N. Lamb of the Forest Service.

directly from the log, and ash heading very largely so. Out of 1,000 feet Doyle scale of small logs, often as many as 5,000 staves can be sawed; while out of 1,000 board feet of sawed lumber only about 2,500 staves can be produced, which indicates the advantage of direct conversion of logs into staves. However, some mills in Texas which are remote from the general hardwood market find it profitable to work up their No. 3 common ash lumber into butter-tub heading.

Ash bolts delivered at the factory manufacturing butter-tub staves and heading are worth from $5 to $10 per cord of 128 cubic feet, and stumpage is worth from $2 to $6 per cord (or from $4 to $12 per 1,000 board feet log scale).

VEHICLES.

Ash is extensively used in all kinds of vehicle construction. A number of qualities of the wood make it suitable for a great variety of vehicle parts; it is very strong for its weight; it is tough and elastic and bends well (especially second-growth ash); it retains its shape; is not likely to warp (especially old growth); and wears well. For parts, such as poles, tongues, shafts, trees, axles, braces, and bottom boards, which require strength and toughness, second-growth white or green ash is used, largely as a substitute for hickory. For parts requiring bending qualities and strength, such as felloes and bows for vehicle tops, second-growth white and green ash is also used. For vehicle bodies of all kinds and for panels old growth of all species of ash is preferred, because it can be obtained in larger sizes and greater widths, is not so likely to warp, and holds glue better than second growth. White and green ash are the leading species of ash used in the vehicle industry; only a small per cent of black ash is used because of its inferior strength and toughness.

About 20 per cent of all the ash used in vehicle construction is for automobiles, and about equal amounts of the remainder are used for wagons and heavy vehicles and for buggies and light vehicles.

The average price of ash lumber used in this industry is high because a large proportion of upper grades is required; and the total cost, delivered at the factory, is greater than in the dairy supply industry. A considerable amount of ash is sawed into special sizes for vehicle stock from small logs. The average price for white ash delivered at the factory ranges from $18 in Tennessee to $142 in Oregon. The general average for the whole country is from $40 to $45. Michigan, Indiana, Ohio, Pennsylvania, and New York are the leading States in the use of ash for vehicles. Ash stumpage suitable for vehicle stock commands from $5 to $25, an average of $15 per 1,000 board feet. Fifteen dollars would be too high, however, in the South, because of the great distance from the market and the high cost of transportation.

PLANING MILL PRODUCTS.

For flooring, ceiling, siding, stairs, window and door frames, cabinet work, mantels, and interior fittings of all kinds, including picture frames and molding, ash is desirable because of its handsomeness of grain and figure, its polishing and wearing qualities, its comparative workability, and because it holds its shape well, is not likely to warp, and is strong. Old growth is uniformly superior to second growth for these purposes, because it retains its shape better, and because clear lumber, often of good width, which can best be secured from large, old-growth trees, is usually required, and strength is a secondary consideration.

Ash used in this industry is secured from all three of the important commercial species—white, green, and black. In proportion to its total cut, black ash probably contributes more than white or green. Black ash is used especially for ceiling, siding, flooring, and cabinet work; and most of the curly ash, highly prized for interior work, is from black ash.

The cost of the ash lumber for planing-mill purposes, delivered at the factory, varies from $10 in Arkansas to $70 in California. The average price is about $31. Stumpage prices of ash to be used for planing-mill products are much the same as for ash to be used for rough lumber and range from $3 to $15, with an average of about $9 per thousand.

REFRIGERATORS AND KITCHEN CABINETS.

Ash is much used in the construction of refrigerators and kitchen cabinets on account of the same quality that make it desirable for dairy use; that is, the absence of any odor which can be absorbed by food. It is also desirable because it works well, holds its shape well, is strong and fairly durable, finishes well, and makes a handsome exterior. A little over 50 per cent of the total ash used in this industry is consumed in Michigan alone, and 22 per cent in Wisconsin. Probably black ash is most used; white ash is used to some extent, and green ash but little, because it is too far away from the factories.

The price paid for ash used in this industry ranges from $24 to $46, and averages about $30 per 1,000 board feet.

FURNITURE, CHAIRS, AND CHAIR STOCK.

Ash is a desirable furniture wood because it has a handsome grain, especially old-growth black ash, finishes well, and takes a high polish; also because it is strong, fairly light, easily worked, has excellent bending qualities, and retains its shape well. In amount used it does not rank high among the species that go into this industry, because of its comparative scarcity and the high price it commands for other purposes. It is used for all kinds of tables and chairs, especially for bent parts, and for desks, filing cabinets, bookcases, racks of all kinds, chamber suits, bureaus, couch frames, stands, piano stools and benches, china closets (inside work), buffets, porch and lawn seats and swings, and parts of reed furniture. It has the quality of being easily racked apart into thin, very elastic strips one-tenth of an inch or less in thickness and an inch or so wide, suitable for splint chair bottoms.

The price paid for ash lumber used in this industry varies from $10 in Alabama to $110 in California, and averages about $27 per 1,000 board feet.

CAR CONSTRUCTION.

Car construction is a very important use for high-priced upper grades of ash lumber, especially timbers of good thickness and width cut from old-growth ash. Ash is sufficiently strong, stiff, tough, and elastic for car frames; it is handsome for interior finish, being susceptible of a high polish, wearing well, and retaining its shape; and its bending qualities make it desirable for bows for bent wood around windows and doors, also for bent panels. The average price for car construction, delivered at the factories, is about $50 per 1,000 board feet. The price of eastern white ash used in car factories in California is $126 per 1,000 board feet. Pennsylvania, Illinois, Missouri, and Ohio are the leading States in the use of ash for car construction. White, green, and black ash are all suitable for this industry.

AGRICULTURAL IMPLEMENTS.

The same qualities which make ash desirable for vehicle construction and for handles make it suitable for agricultural implement parts of all kinds. The States leading in the use of ash for this purpose are Arkansas, Michigan, New York, Indiana, and Pennsylvania. The price paid ranges mostly from $20 to $60 and averages about $40 per 1,000 board feet. In California $116 was paid for ash used in this industry. Second-growth white and green ash are most used, and the proportion of black ash is very small.

BOXES AND CRATES.

Ash lumber and logs of the lower grades and of inferior quality are used to a moderate extent in the construction of boxes, crates, and baskets, for which purposes ash is desirable wherever it can be purchased at a sufficiently low price. It is excellent for boxes or portions of boxes requiring strength, such as the bottoms of piano cases. Where there is considerable low-grade ash, it is used for vegetable and fruit crates, especially black ash at some points in the Lake States and green ash in the South. In basketwork ash is used for bent-frame parts and for slats or splints to baskets made by racking apart thin strips between the annual rings. Black ash is the chief ash used in basketwork. The Indians of New England taught the white settlers the art of making splint baskets from black ash.

The price of ash used for boxes, crates, and baskets ranges mostly from $10 to $25, and averages about $14 per 1,000 board feet. Michigan, Illinois, Texas, and Wisconsin are the leading States in the use of ash for this industry.

SHIPS AND BOATS.

The chief use of ash in the ship and boat industry is for oars, into which goes over 80 per cent of the total. Practically all long oars and sculls (14 feet and over in length) and a very large proportion of short oars and paddles are made of ash. The United States supplies the world with ash boat oars, both in the rough and finished. A combination of qualities makes ash superior to other woods for oars—it is elastic to a high degree, and is tough, strong, and comparatively light; it is straight grained and easily worked, takes a good polish, wears smooth, and lasts fairly well. Ash for oars is mostly green ash from Tennessee, Mississippi, Louisiana, and Arkansas. Ash logs for oars cost, delivered at the factory, from $20 to $40 per 1,000 board feet, and about $30 on the average. They must be straight and free from defects, 8 feet and up in length, and 12 inches and up in diameter at the top end. White ash was originally the chief supply for oars until it became too scarce. Black ash is not suitable, as it will water-soak, becoming soft and spongy.

Ash is used to a small extent in general ship and boat construction for frames for small craft, tillers for canal boats, interior finish, benches, ribs, and keels.

SPORTING AND ATHLETIC GOODS.

The qualities of ash that make it an unusually desirable wood for baseball bats, tennis racquets, snowshoes, skis, polo sticks, hockey sticks, gymnasium goods, billiard tables, bowling alleys, fishing rods, and playground equipment are its high elasticity, toughness, strength, and comparative lightness. For baseball bats ash is used almost to the exclusion of other woods; it supplies a very large proportion of tennis-racquet frames, polo sticks, and hockey sticks. Ash used in this industry is mostly tough second-growth white ash, ranging usually in price from $30 to $50 per 1,000 board feet for lumber delivered at the factory. The stock is often specially sawed with reference to the particular use to which it is to be put, as for baseball bats. In New England, in this industry, ash is often bought in log or bolt form, and $40 to $50 per 1,000 paid for good clear stuff delivered to the factory.

FIXTURES.

Ash is a desirable wood for fixtures because of its handsome grain and finishing qualities and because it is durable, wears smooth, and is tough and strong. It is used especially for store, office, bank, school, and church fixtures, including railings, counter tops, show cases, cabinets, partitions, seats, and pews. The price of ash for fixtures averages about $37 per 1,000 board feet, considerable lumber of upper grades being used. Ohio, Illinois, Michigan, and Iowa lead in the use of ash for fixtures. All three of the important commercial species are used.

MUSICAL INSTRUMENTS.

Ash is used to a moderate extent in the construction of various kinds of musical instruments, including pianos, organs, piano players, banjos, harps, and tambourines. It is used for piano frames, backs, keys, inside work, and molding. It is a substantial wood for musical instruments, as it holds its place well, finishes and wears well, is easily worked, and is tough and strong. The better grades of ash lumber are used almost exclusively, and the price paid at the factory averages about $55. Illinois, New York, Maryland, and Missouri are the leading States using ash in musical instruments. White, green, and black ash are all used in this industry.

WOODENWARE AND NOVELTIES.

Ash woodenware and novelties include chiefly ladder rounds, stepladders, buckets, pails, tubs, staffs, small flagpoles, butchers' blocks, and carving boards. The qualities which make ash desirable in these articles are, in general, its straightness of grain, strength, workableness, and wearing ability. Lumber of the lower grades is used most, because it is largely sawed up into short pieces, so that defects can be readily eliminated where desired. The average price at the factory for the ash lumber used is about $29 per 1,000 board feet. The price of material used for buckets ranges low, while that for ladders is high.

SADDLES AND HARNESS.

Hames are made from over 80 per cent of the ash used in the saddle and harness business. Ash is especially desirable for hames because it is strong and tough yet comparatively light. It is also used for saddletrees and stirrups. Second-growth white ash is the most desirable and is chiefly used. The price paid averages $35 per 1,000 board feet, delivered at the factories. Eighty per cent of the total is used in New Hampshire and New York.

MACHINE CONSTRUCTION.

Ash is suitable for frames in machine construction and machine parts because it is a strong, tough, dependable wood, and is straight-grained and easily worked. Considerable ash of upper grades is used. The price paid averages about $45 per 1,000 board feet, delivered at the factory. White ash is used most. Two-thirds of the total amount of ash in this industry is used in Illinois, and a quarter of it in New York and Wisconsin.

PUMPS.

The chief use for ash in pumps is for sucker rods, for which it is adaptable because its straight grain and workableness make possible the cutting out of strong rods of small diameters. Considerable black ash is used. Tennessee uses over half of the total. The price paid is low—from $14 to $25 per 1,000 board feet—because factories are located near the source of supply and buy material in the log.

TOYS.

Ash is of considerable importance in the toy-making industry in New York, Pennsylvania, and Wisconsin. The average price paid for the ash lumber used is about $33. Old-growth ash, especially black ash, will usually best fulfill the requirements, as it holds glue better than second-growth and is not so likely to warp.

TANKS, SILOS, AND WINDMILL PARTS.

White ash is used to a minor extent for tanks, silos, and windwill parts in New York, Illinois, and Wisconsin. In New York it is low-grade material for tanks and silos; in Illinois and Wisconsin it is high-priced ash for windmill parts. The average price for ash in this industry is about $33.

PLUMBERS' WOODWORK.

Ash is used for plumbers' woodwork in Vermont, Pennsylvania, Ohio, and Illinois. Drainboards, connected with sinks, are often made of ash, as it is exceedingly well adapted for this use. The average price paid for lumber used in this industry is about $25 per 1,000 board feet.

TRUNKS.

Ash is a desirable wood for trunks, although only a small amount of it is used in proportion to some other species. The greater part of a trunk is usually made out of some lighter wood, such as basswood. Ash is suitable for bottoms, corners, tops, and slats. The price paid averages about $35 per 1,000 board feet.

PULLEYS AND CONVEYORS.

Only a small amount of ash is required in the manufacture of pulleys and conveyors. The average price paid is low, about $29 per 1,000 board feet, as short lengths can be used. Connecticut and New York are the leading States in amount used. In this industry ash is an important wood for tackle-block material, and to a lesser extent for belt pulleys and conveyors.

PICKER STICKS AND BOBBINS.

Ash lumber for picker sticks costs about $27 per 1,000 board feet. Some ash is used for bobbins.

PRINTING MATERIAL.

Ash for printing material is used chiefly in Michigan. The average price paid for the lumber is low, about $23 per 1,000 board feet, because it is near the source of supply and because lumber of the lower grades can be used.

PICTURE FRAMES AND MOLDING.

Ash is a wood of less importance in the manufacture of picture frames and molding. It is used chiefly in Illinois, Michigan, Wisconsin, and Maryland. Old-growth black ash is probably preferable for this use. The average price paid is rather high—about $37 per 1,000 board feet, delivered at the factory.

PLAYGROUND EQUIPMENT.

Ash is an excellent wood for use in playground equipment because of its ability to wear smooth and because of its comparative strength and lightness. The average price paid for ash lumber for this use is about $31 per 1,000 board feet.

SHADE AND MAP ROLLERS.

Ash is of some importance in the manufacture of shade and map rollers, and especially for curtain poles in Tennessee. The average price paid for lumber, about $23 per 1,000 board feet, is low because the factories are near the source of supply.

ELEVATORS.

Ash is of considerable importance in elevator making in Pennsylvania. It is used chiefly for guide strips because of its ability to wear smooth. The average price paid is high—about $69 per 1,000 board feet.

PROFESSIONAL AND SCIENTIFIC INSTRUMENTS.

Ash is used for tools and instruments, especially for carpenter's tools. More is used for this purpose in New Jersey than elsewhere. The average price paid is high—about $62 per 1,000 board feet.

AEROPLANES.[1]

Ash is the second most important wood used in aeroplanes. The great bulk of the wood used is spruce from the Pacific coast and West Virginia. The essential qualities needed in wood for aeroplanes are straightness of grain, strength, absolute freedom from hidden defects, lightness (in comparison with strength), and ability to stand extreme stress. Ash is used in framework, main outriggers on which the canvas is stretched, uprights bearing the engine or forming the engine bed, skids (on the upright, curving ends of which the alighting wheels are fixed), rudders, and propeller blades. For framework, outriggers, and uprights straightness of grain and strength are the essential qualities needed, which usually can be best supplied by rapid-growing, comparatively young growth, from 75 to 150 years old. For propeller blades, for which ash is very largely used, the quality desired, in addition to strength in comparison with weight, is ability of the wood to hold its shape, which is best supplied by old-growth ash. Propeller blades are made from laminated blocks consisting of several layers of different kinds of wood glued and nailed together. An excellent combination is said to be a middle layer of ash with spruce on either side, then layers of mahogany on the spruce, and thin layers of ash on the outside.[2] Engine blocks and frame ribs are also often laminated in construction, spruce and ash being combined to divide the stress.

The average price for ash lumber used for aeroplanes is very high, about $65 per 1,000 board feet, and there is much waste in utilization. A Chicago firm in 1912 paid $180 for 600 feet of specially sawed ash, or at the rate of $300 per 1,000 feet, which is probably a record price for ash lumber.

EXPORT.

From five to seven million feet of ash logs are exported annually to Europe, chiefly green ash from the South Atlantic and Gulf States. Export dealers pay from $30 to $40 per 1,000 board feet

[1] Information supplied by J. T. Harris, Office of Industrial Investigations, Forest Service.

[2] Great trouble has been experienced from the splitting and checking of wooden aeroplane propellers, when made from laminated blocks either of a single material or of different woods. This can best be prevented by use of thoroughly air-seasoned woods, and by keeping propellers out of doors at all times, or by giving them a coating of paraffin to prevent the entrance of moisture.

(Doyle scale) for rafts of ash logs delivered for loading on trans-Atlantic steamers, and make a good margin of profit on the operation. The logs are mostly 12 inches and up in top diameter, and 12 feet and up in length, although some smaller logs down to 6 inches in diameter are also exported. The exporters figure that the smaller amount of timber shown by Doyle's rule in proportion to what can be cut out from the smaller sized logs warrants paying the same price.

Several million feet of ash lumber, in deal or plank form, are also exported yearly to Europe and South America.

During the last part of the eighteenth century American ash began to supplant European ash (from the Baltic region) in English shipbuilding, because of its superior qualities, and large quantities were exported to England for this purpose for nearly a century. It is used for rafters, oars, capstans, bars, blocks, levers, handspikes, pins, etc.

FUEL.

The chief minor use of ash is for fuel, for which green ash is especially used in parts of the Southern States, such as localities along the lower Mississippi River where there is not much pine. It is very easily split, comparatively light, and makes a quick, hot fire. A fairly large quantity of ash finds its way to fuel yards, and charcoal burners also use much of it. Ash has a fuel value of about 90 per cent of that of oak.

FENCING AND OTHER FARM USES.

Ash is used to a minor extent for fence posts and rails in places where better suited timber is not available, such as the Prairie and Plains States. Black and blue ash are the most durable ash woods for posts, but all species make strong, light rails. Ash is good for rough and ready wagon poles cut by the farmer. The possibilities in these and other general farm uses can be greatly extended by creosoting.

MISCELLANEOUS.

Black ash is used for mine timbers. It has also been used successfully for chemical pulp, along with birch, beech, and maple, by one large concern in Elk County, Pa. White, green, black, and Oregon ash bark is used to a limited extent in the drug business—after the removal of the outside corky layer. From three to five cents per pound is paid to collectors of this material. It is not, however, an official drug and is of small commercial importance. Ash wood is distilled to a very limited extent along with birch, beech, and maple for the production of wood alcohol, acetate, and charcoal. Sticks of black ash are used occasionally in mixture with other hardwoods for chemical pulp. Ash saplings, an inch or so in diameter, are used in New England for barrel hoops in the absence of hickory. They are split into two to four pieces, and the hoops made from 4½ to 10 feet long. The hoops bring $4.50 to $12 per 1,000, depending on the size, and cost $2 to $4 per 1,000 to produce.

LUMBER AND STUMPAGE VALUES.

ASH LUMBER PRICES.

Present wholesale prices of different grades of ash lumber in the principal centers of its distribution are given in Table 13. These prices are for ash in car lots as sold to the retail and factory trades. They are based on lumber properly manufactured and graded under the grading rules of the National Hardwood Lumber Association and, to a less extent, those of the Hardwood Manufacturer's Association. These two rules are quite similar in wording, but the former requires inspection to be made on the poorer side of the piece, while the latter requires both sides to be considered in determining the grade. Also, the latter has a grade of No. 4 common which the former does not have. Inspection on one side is more satisfactory from the jobber's standpoint, while inspection on both sides is preferable to the manufacturers.

The standard lengths for ash lumber are from 4 to 16 feet, and the standard thicknesses are usually 1, 1¼, 1½, 2, 2½, 3, and 4 inches when dry.

Bright sap is no defect in the "first and seconds" grade in ash, while in plain sawed oak it is only admitted as no defect when less than one-half the width of the board in the aggregate on the one side, and in quarter-sawed oak when not over 1 inch in pieces 8 inches and over wide. This makes the grading of ash less rigid than that of oak.

TABLE 13.—*Wholesale prices*[1] *of ash lumber in important centers of lumber distribution and utilization.*

[Prices are per 1,000 board feet.]

	Firsts and seconds, 5 inches and up wide.			No. 1 Common, 4 inches and up wide.			No. 2 Common, 3 inches and up wide.			No. 3 Common, 3 inches and up wide.		
	1 inch thick.	2 inches thick.	4 inches thick.	1 inch thick.	2 inches thick.	4 inches thick.	1 inch thick.	2 inches thick.	4 inches thick.	1 inch thick.	2 inches thick.	4 inches thick.
Boston	$53.50	$65.00	$79.50	$38.50	$44.00	$57.00	$29.50	$30.50	$35.50	$21.50	$22.50	$24.50
New York	53.00	64.50	79.00	38.00	43.50	56.50	29.00	30.00	35.00	21.00	22.00	24.00
Buffalo	49.50	61.00	75.50	36.50	40.00	53.00	25.50	26.50	31.50	17.50	18.50	20.50
Philadelphia, Baltimore, and Washington	52.00	63.50	78.00	37.00	42.50	55.50	28.00	29.00	34.00	17.00	17.00	20.00
Pittsburgh	49.50	61.00	75.50	34.50	40.00	53.00	25.50	28.50	31.50	17.50	18.50	20.50
Richmond and Norfolk	49.00	60.00	75.00	33.00	38.50	51.50	25.00	26.00	31.00	17.00	18.00	20.00
Knoxville	42.00	53.50	67.00	28.00	32.50	45.00	18.00	19.00	23.50	10.00	11.00	13.00
Nashville	42.00	53.50	68.00	27.00	32.50	45.50	18.00	19.00	24.00	10.00	11.00	13.00
Louisville	45.00	56.00	75.00	30.00	35.00	46.00	18.00	23.00	28.00	12.00	13.00	16.00
Cincinnati	46.00	57.50	72.00	31.50	36.50	51.50	22.00	23.00	28.00	14.00	15.00	17.00
Evansville	45.50	57.00	71.50	30.50	36.00	49.00	21.50	22.50	27.50	13.50	14.50	16.50
Chicago and Indianapolis	47.50	59.00	73.50	32.50	38.00	49.00	23.50	24.50	29.50	15.50	16.50	18.50
Detroit, Cleveland, and Grand Rapids	49.00	60.50	75.00	33.00	39.50	52.00	25.00	26.00	31.00	17.00	18.00	20.00
Wausau, Wis	43.50	54.00	69.50	28.50	34.00	47.00	19.50	19.50	26.50	11.50	12.50	14.50
St. Paul and Minneapolis	50.00	61.50	76.00	35.00	40.50	53.50	25.00	27.00	32.00	17.00	19.00	21.00
St. Louis	45.00	56.50	71.00	30.00	35.50	46.50	21.00	22.00	29.50	13.00	14.00	16.00
Kansas City	46.50	58.00	72.50	31.50	37.00	50.00	22.50	23.50	28.50	14.50	15.50	17.50
Denver	45.00	66.50	81.00	40.00	45.50	60.50	31.00	32.00	37.00	......	......	......
Los Angeles, San Francisco, and Seattle	63.50	75.00	89.50	......	......	......	......	......	......	......	......	......
Cairo and Thebes	44.00	55.50	70.00	29.00	33.50	48.50	20.00	21.00	26.00	12.00	13.00	15.00
Memphis	41.00	52.50	67.00	26.00	31.50	42.50	17.00	18.00	23.00	9.00	10.00	12.00
New Orleans	44.00	55.50	70.00	29.00	34.50	47.50	20.00	21.00	26.00	12.00	13.50	15.00

[1] Figures taken from the market report of Sept. 15, 1916, of the Lumberman's Bureau, Washington, D. C. These prices claim to represent actual selling prices in the principal markets of lumber in car lots to the retail and factory trade.

The f. o. b. value of properly manufactured and graded ash lumber at any particular mill is the difference between its wholesale value at the nearest city in the list given in the table and the wholesaler's profit and expenses—the latter chiefly freight. In some cases the f. o. b. mill value should be more, as where the timbers can be marketed locally or at a point with a lower freight rate than to any given in the list or where the wholesaler's profit can be eliminated.

Small second-growth ash logs which would not cut a high per cent of upper grades are often worth more f. o. b. mill for shipment to some factory for special uses, such as for handles of all kinds, than if manufactured into graded lumber. In Ohio such logs to be used for handles are worth from $30 to $40 per 1,000 feet log scale delivered at factory, which admits of a $15 to $35 value per 1,000 board feet for logs f. o. b. local station for material too small in diameter to cut out more than a very small per cent of upper grades. In Arkansas from $15 to $20, and in Virginia $40, is paid for ash logs for handles, delivered at the factories.

Ash logs for export command an equally high price, which offers an important prospective market for ash grown under forest management where there is cheap transportation to the coast.

Table 14 gives the average wholesale price f. o. b. mill for ash lumber in various States from 1909 to 1916.[1]

The prices quoted are for one inch (4/4) thick lumber of the firsts and seconds, No. 1 common, and No. 2 common grades, and mill-run values or average prices for all grades produced.

TABLE 14.—*Average wholesale prices of ash lumber (per 1,000 board feet) in various States, based on actual sales made f. o. b. mill for the years 1909–1916.*

State.	1909	1910	1911	1912	1913	1914	1915	1916
Alabama:								
Firsts and seconds, 4/4	$35.50	$33.50	$35.59	$35.29	$42.44	$44.46	$44.50	....
No. 1 common, 4/4	22.17	22.33	22.67	21.04	25.50	25.96	24.50	....
No. 2 common, 4/4	11.09	14.32	13.25	10.84	15.19	15.08	14.83	....
Mill run	....	....	....	....	26.12	23.50	22.25	....
Arkansas:								
Firsts and seconds, 4/4	36.62	36.90	35.94	36.64	41.49	41.08	39.89	$40.00
No. 1 common, 4/4	21.31	20.43	20.12	21.42	25.00	23.46	26.04	26.35
No. 2 common, 4/4	10.91	11.15	10.93	11.25	13.67	13.62	11.74	....
Mill run	21.10	22.20	20.60	20.33	....	22.00	27.98	....
Connecticut:								
Firsts and seconds, 4/4	27.00	37.50	....	....	....	....	....	....
No. 1 common, 4/4	30.00	....	....	24.12	....	....	....	....
No. 2 common, 4/4	21.00	....	....	....	....	....	....	....
Mill run	20.62	21.49	21.36	17.82	....	....	....	....
Indiana:								
Firsts and seconds, 4/4	38.78	40.33	40.10	39.18	....	....	....	....
No. 1 common, 4/4	25.39	25.19	25.24	25.91	....	....	....	....
No. 2 common, 4/4	15.94	18.20	18.78	16.40	....	....	....	....
Mill run	23.30	25.89	26.46	22.15	....	....	....	....
Illinois:								
Firsts and seconds, 4/4	37.13	37.73	41.25	....	....	....	....	....
No. 1 common, 4/4	22.62	24.93	25.00	24.67	....	....	....	....
No. 2 common, 4/4	12.81	....	17.38	....	....	....	....	....
Mill run	23.89	....	....	....	....	....	....	....
Kentucky:								
Firsts and seconds, 4/4	38.01	37.82	38.05	39.20	46.08	44.25	45.17	46.00
No. 1 common, 4/4	23.41	24.30	24.17	24.47	29.80	27.00	28.17	26.00
No. 2 common, 4/4	13.52	16.00	16.52	14.79	17.36	16.00	16.67	16.00
Mill run	22.44	21.65	20.89	19.75	29.41	26.00	....	28.00
Louisiana:								
Firsts and seconds, 4/4	35.42	35.50	35.15	36.30	32.67	37.00	37.12	38.50
No. 1 common, 4/4	20.84	21.12	19.32	19.74	18.67	21.62	21.88	23.00
No. 2 common, 4/4	10.84	10.47	10.27	10.87	9.33	11.88	11.75	13.00
Mill run	....	20.57	....	18.67	22.17	25.50	24.18	....
Massachusetts:								
Firsts and seconds, 4/4	30.00	....	....	....	....	....	....	....
No. 1 common, 4/4	....	....	....	24.20	....	....	....	....
No. 2 common, 4/4	....	....	....	....	....	....	....	....
Mill run	21.63	21.45	21.76	18.67	....	....	....	....
Missouri:								
Firsts and seconds, 4/4	36.23	38.48	37.22	....	43.50	38.38	40.38	39.75
No. 1 common, 4/4	22.28	23.19	22.00	....	29.00	24.00	24.46	23.75
No. 2 common, 4/4	12.31	14.10	15.00	12.67	17.50	13.88	15.04	13.75
Mill run	25.79	20.25	20.84	....	....	20.25	22.03	20.00
Michigan:								
Firsts and seconds, 4/4	39.25	38.14	39.66	39.22	42.00	....	....	....
No. 1 common, 4/4	28.26	27.58	26.71	26.18	32.00	....	....	....
No. 2 common, 4/4	17.04	25.53	25.42	17.53	30.44	31.52	....	....
Mill run	22.63	22.18	21.87	20.68	22.25	21.34	....	....
Mississippi:								
Firsts and seconds, 4/4	35.98	36.28	35.26	34.88	37.44	40.25	40.79	38.33
No. 1 common, 4/4	21.44	22.70	20.58	22.33	22.33	24.62	23.33	23.00
No. 2 common, 4/4	10.97	10.80	10.56	10.96	10.67	14.00	13.75	13.00
Mill run	29.33	20.50	24.00	....	32.11	....	25.50	30.00

[1] Based on reports of actual sales, received by the Forest Service from a number of the largest manufacturers in the different States.

TABLE 14.—*Average wholesale prices of ash lumber (per 1,000 board feet) in various States, based on actual sales made f. o. b. mill for the years 1909–1916*—Continued.

State.	1909	1910	1911	1912	1913	1914	1915	1916
North Carolina:								
Firsts and seconds, 4/4	$38.19	$39.21	$38.29	$38.84	$38.00	$26.67	$38.62	$38.00
No. 1 common, 4/4	25.67	26.71	25.35	24.84	24.00	25.33	25.25	26.00
No. 2 common, 4/4	12.84	12.33	14.94	12.50	11.00	14.00	13.75	13.00
Mill run	17.00	15.85	15.50	....	....	24.00	26.67	27.00
New York:								
Firsts and seconds, 4/4	39.74	44.27	42.96	39.98	....	....	....	....
No. 1 common, 4/4	28.76	30.50	28.33	26.96	....	....	....	....
No. 2 common, 4/4	16.02	20.32	22.44	18.16	....	....	....	....
Mill run	23.96	22.76	23.77	20.88	....	....	....	....
New Hampshire: Mill run	22.95	22.42	20.50	19.78	....	....	....	....
Ohio:								
Firsts and seconds, 4/4	41.65	43.18	42.02	38.64	47.00	55.00	49.62	50.00
No. 1 common, 4/4	28.01	28.92	28.76	28.03	28.50	34.00	30.00	30.00
No. 2 common, 4/4	17.07	19.01	18.55	17.28	17.50	23.00	21.00	20.00
Mill run	25.53	25.31	25.44	....	19.50	27.00	30.40	26.00
Pennsylvania:								
Firsts and seconds, 4/4	39.17	41.11	36.94	40.00	....	....	....	....
No. 1 common, 4/4	29.11	28.01	25.75	26.50	....	....	....	....
No. 2 common, 4/4	17.44	23.07	20.50	....	....	....	....	....
Mill run	25.40	25.95	25.09	21.85	....	....	....	....
South Carolina:								
Firsts and seconds, 4/4	....	38.25	....	....	....	....	....	....
No. 1 common, 4/4	....	19.00	....	....	....	....	....	....
Texas:								
Firsts and seconds, 4/4	....	37.97	39.40	....	....	....	....	....
No. 1 common, 4/4	....	22.15	22.40	....	....	....	....	....
No. 2 common, 4/4	....	10.91	12.50	....	....	....	....	....
Mill run	....	....	....	....	....	....	....	....
Tennessee:								
Firsts and seconds, 4/4	39.88	37.39	38.04	36.51	45.68	41.99	41.42	42.83
No. 1 common, 4/4	24.79	23.41	24.00	22.86	28.82	26.41	25.60	26.33
No. 2 common, 4/4	13.54	14.50	13.16	12.36	17.57	16.18	15.98	16.00
Mill run	23.63	20.74	21.96	20.50	....	....	....	30.00
Virginia:								
Firsts and seconds, 4/4	37.97	37.54	36.88	37.09	....	....	....	....
No. 1 common, 4/4	25.51	25.22	23.60	25.33	....	....	....	....
No. 2 common, 4/4	13.20	17.01	13.23	12.11	....	....	....	....
Mill run	26.50	19.00	....	....	....	....	....	....
Vermont:								
Firsts and seconds, 4/4	25.20	29.00	....	....	....	....	....	....
No. 1 common, 4/4	24.25	23.50	....	26.00	....	....	....	....
No. 2 common, 4/4	19.33	17.33	17.00	....	....	....	....	....
Mill run	20.51	18.09	20.26	20.03	....	....	....	....
West Virginia:								
Firsts and seconds, 4/4	41.03	42.40	42.52	40.47	46.64	46.62	43.88	43.00
No. 1 common, 4/4	28.65	27.84	28.17	28.49	30.86	29.63	26.88	27.00
No. 2 common, 4/4	14.73	18.44	20.71	14.89	18.72	18.88	16.88	17.00
Mill run	21.78	22.79	23.56	18.00	21.50	....	....	....
Wisconsin:								
Firsts and seconds, 4/4	37.27	36.19	36.66	37.54	43.40	47.67	....	....
No. 1 common, 4/4	25.00	24.79	23.44	23.94	30.62	33.75	....	....
No. 2 common, 4/4	13.78	23.17	22.08	14.42	28.72	31.10	....	....
Mill run	21.02	19.73	18.74	18.28	22.73	15.00		

Table 15 gives the average wholesale prices for white and brown ash lumber in various markets for 1908 to 1912.[1] The prices quoted are for 1-inch (4/4) thick lumber only, including firsts and seconds and No. 1 common white ash, and firsts and seconds, No. 1 common, and No. 2 common brown ash.

[1] Based on reports of actual sales, received by the Forest Service from many of the the largest wholesalers in each of the markets quoted.

TABLE 15.—*Average wholesale prices of ash lumber (per 1,000 board feet) in various markets, based on actual sales made f. o. b. each market.*

Market.	1908	1909	1910	1911	1912
Boston:					
White ash—					
Firsts and seconds, 4/4	$53.32	$51.67	$52.83	$52.17	$52.42
No. 1 common, 4/4	40.75	36.17	36.08	35.50	35.25
Brown ash—					
Firsts and seconds, 4/4	54.67	52.46	56.88	54.81	54.92
No. 1 common, 4/4	....	41.17	45.00	35.25	....
New York:					
White ash—					
Firsts and seconds, 4/4	50.29	50.00	50.00	50.94	51.67
No. 1 common, 4/4	35.54	35.38	32.50	33.50	33.08
Brown ash—					
Firsts and seconds, 4/4	50.67	50.00	55.00	53.25	....
No. 1 common, 4/4	37.00	35.58	37.67	37.75	....
No. 2 common, 4/4	....	22.50	25.00	....	....
Philadelphia:					
White ash—					
Firsts and seconds, 4/4	50.96	49.52	52.50	49.25	49.50
No. 1 common, 4/4	33.00	34.46	32.00	32.75	33.12
Norfolk:					
White ash—					
Firsts and seconds, 4/4	....	45.50	....	....	....
No. 1 common, 4/4	....	28.50	....	....	....
Buffalo:					
White ash—					
Firsts and seconds, 4/4	52.14	50.29	51.44	51.06	51.25
No. 1 common, 4/4	33.58	32.86	32.75	32.50	31.67
Brown ash—					
Firsts and seconds, 4/4	53.17	51.63	53.06	51.83	52.00
No. 1 common, 4/4	33.67	33.33	33.38	32.75	31.67
No. 2 common, 4/4	....	39.00	21.17	21.63	21.33
Pittsburgh:					
White ash—					
Firsts and seconds, 4/4	48.25	50.25	51.31	49.42	....
No. 1 common, 4/4	36.00	35.25	33.75	33.75	....
Cincinnati:					
White ash—					
Firsts and seconds, 4/4	42.67	43.58	44.56	43.44	45.17
No. 1 common, 4/4	29.97	29.08	28.81	27.25	28.92
Chicago:					
White ash—					
Firsts and seconds, 4/4	46.14	45.41	44.38	46.00	45.33
No. 1 common, 4/4	29.83	29.02	29.17	29.50	28.67
Brown ash—					
Firsts and seconds, 4/4	....	39.75	37.25	....	....
No. 1 common, 4/4	....	29.50	26.38	....	....
No. 2 common, 4/4	....	16.00	....	....	....
St. Louis:					
White ash—					
Firsts and seconds, 4/4	39.82	40.34	41.00	41.06	41.42
No. 1 common, 4/4	24.79	23.94	24.13	24.75	25.58
Memphis:					
White ash—					
Firsts and seconds, 4/4	39.68	39.60	39.25	38.31	40.25
No. 1 common, 4/4	23.36	23.41	23.38	23.00	24.00
Minneapolis:					
White ash—					
Firsts and seconds, 4/4	38.88	49.25	49.00	43.63	....
No. 1 common, 4/4	28.75	32.00	32.17	28.00	....
Brown ash—					
Firsts and seconds, 4/4	....	38.24	36.92	36.25	37.08
No. 1 common, 4/4	....	27.64	26.00	25.00	25.75
No. 2 common, 4/4	....	16.75	15.42	15.00	15.67
Kansas City:					
White ash—					
Firsts and seconds, 4/4	48.75	45.25	....	49.75	....
No. 1 common, 4/4	30.00	26.50	....	33.25	....
New Orleans:					
White ash—					
Firsts and seconds, 4/4	....	....	35.75	36.25	38.25
No. 1 common, 4/4	....	....	19.00	20.81	22.25
Denver:					
White ash—					
Firsts and seconds, 4/4	51.15	49.50	....	53.25	....
San Francisco:					
White ash—					
Firsts and seconds, 4/4	107.50	98.28	101.88	94.12	96.75
Los Angeles:					
White ash—					
Firsts and seconds, 4/4	89.75	89.38	81.67	85.00	....

Table 16 shows delivered wholesale prices of white ash inch boards of different grades in Boston, New York, Philadelphia, and St. Louis from 1896 to 1910, inclusive, from figures published by the Bureau of Corporations, Department of Commerce and Labor, based on actual sales in the different markets. That bureau also obtained prices on brown ash, which in the early years showed a price movement somewhat different from that of white ash, but which in later years was much the same.

TABLE 16.—*Actual prices of white ash delivered in Boston, New York, Philadelphia, and St. Louis, 1896–1910 (for rough, 1 inch thick boards).*

Year.	Firsts and seconds.				No. 1 common.			No. 2 common.	
	Boston.	New York.	Philadelphia.	St. Louis.	New York.	Philadelphia.	St. Louis.	New York.	Philadelphia.
1896	....	$34.62	....	....	....	....	....	....	....
1897	$35.75	32.00	....	....	$20.50	....	$14.38	$14.50	....
1898	37.50	32.50	....	$25.81	22.67	....	15.75	14.33	....
1899	39.18	37.92	....	34.17	29.00	....	21.45	18.70	....
1900	42.20	39.00	$35.00	32.34	28.88	....	22.00	20.00	....
1901	42.38	38.70	38.25	30.61	27.90	$25.50	20.38	18.10	$14.50
1902	41.42	40.20	40.00	32.08	28.00	27.54	20.21	19.50	16.50
1903	44 40	42.30	39.89	33.96	31.25	27.47	21.71	21.50	16.33
1904	44.67	45.00	40.25	34.07	30.00	28.08	20.54	22.00	15.33
1905	45.38	46.38	41.20	34.39	30.00	28.28	20.50	22.00	17.04
1906	49.25	48.94	45.81	38.72	33.71	33.14	25.03	21.50	18.16
1907	57.00	54.33	51.07	47.56	39.86	38.85	27.40	....	20.65
1908	54.17	50.00	44.44	38 00	35.50	32.60	23.67	22.67	19.20
1909	49.00	48.75	45 22	40.31	36.75	32 60	24.17	22.67	17.58
1910	52.00	52.44	46.11	41.92	....	33.00	22.40	25.00	18.25

COST OF PRODUCTION.

There are a number of factors that cause great variation in the cost of producing ash lumber f. o. b. local stations: Distance of timber from the railroad; character of transportation, by train or by horses, and whether over good or poor roads; cost of labor and horse teams; location of the mill, whether portable and located in the timber, or stationary and located on the railroad; and the character of the timber, whether in heavy stands or situated so as to be easily skidded, or the opposite of these. The range in logging and lumbering costs for ash timber located from 6 to 10[1] miles from the railroad shipping point (or where an average of one trip a day team haul is possible) is given in Table 17 separately for (*a*) portable mill lumbering; (*b*) small stationary mill lumbering with log transportation by horses and mill located on railroad; (*c*) large stationary mill lumbering with log transportation by steam and mill located on railroad. It is apparent from this table that steam logging is the cheapest where there is sufficient timber to be logged to warrant putting in a railroad or train outfit. In reckoning the

[1] This distance taken as being greater than the average and hence conservative; for shorter hauls the cost of production would be cheaper, while for longer hauls it would be increasingly higher.

profitableness of forest management for ash, seldom, if ever, will it be safe to count on using steam logging, as the areas under management will be too small. The greater cost of the stationary over the portable mill logging (where horses are used to haul the logs) is offset considerably by the greater possibilities of profitable disposal of mill-cull lumber and slabs by the former, and by the possibilities of closer utilization and better manufacture, resulting in a greater output and better grades of lumber. Furthermore, very small lots of timber containing from 5,000 to 10,000 feet or less in a place can often be profitably logged to a stationary mill, while a minimum of from 50,000 to 100,000 feet is usually necessary to make it profitable to set up a portable mill. (See Pls. II and III.)

TABLE 17.—*Cost of producing ash lumber f. o. b. shipping point from timber located from 6 to 10 miles distant.*

A. PORTABLE MILL IN THE TIMBER.

[Minimum stand to be cut 100,000 feet.]

	Low.	Average.	High.
Cutting and bucking up[1]	$1.00	$1.50	$2.00
Skidding to mill, average distance one-fourth mile	2.50	4.00	5.50
Sawing and yarding of lumber	3.00	4.00	5.00
Hauling and loading on cars	2.50	4.00	5.50
Depreciation	1.00	1.00	1.00
Total	10.00	14.50	19.00

B. SMALL STATIONARY MILL ON THE RAILROAD WITH HORSE LOG TRANSPORTATION.

[No minimum limit to the amount cut from one particular stand.]

Cutting and bucking up	$0.75	$1.25	$1.75
Skidding, loading, and hauling logs to mill	7.50	10.00	12.50
Sawing	3.00	4.00	5.00
Depreciation	1.00	1.00	1.00
Total	12.25	16.25	20.25

C. LARGE STATIONARY MILL ON THE RAILROAD WITH STEAM LOG TRANSPORTATION.

[Minimum limit of 10 million feet on tract logged.]

Cutting and bucking up	$0.75	$1.25	$1.75
Skidding, average distance one-half mile	2.75	4.50	6.00
Loading and hauling logs to mill by steam	1.50	2.50	3.50
Milling, including sticking and loading	3.00	4.00	5.00
Depreciation	1.00	1.00	1.00
Total	9.00	13.25	17.25

[1] The range in costs is higher here than in B and C because the operations usually are smaller and more expensive.

VALUE OF STANDING TIMBER.

The value of standing ash timber in any particular locality may be figured by subtracting from its local f. o. b. value the cost of production and a reasonable margin for profit on the money invested.

Twenty per cent of the cost of production is here allowed for profit in figuring what future ash stumpage, grown under forest management, will be worth, and on this basis Table 18 is constructed, which gives for different costs of production the value of standing ash timber which, when produced, will sell (mill-run) f. o. b., at the different prices indicated.

Ash stumpage to be used for other purposes than lumber, as for handles, oars, etc., will sometimes be worth more, especially small second-growth trees conveniently located which would not cut out a high per cent of upper grades of lumber because the boards would be too narrow. Stumpage values of ash used in different industries have already been referred to (see pp. 28 to 31).

TABLE 18.—*Stumpage values per 1,000 board feet for different f. o. b. mill values and different costs of lumbering, allowing 20 per cent margin for profit on cost of lumbering.*

F. o. b. mill value.	Cost of lumbering.[1]					
	$10	$12	$14	$16	$18	$20
Per 1,000 board feet.	Stumpage[2] value per 1,000 board feet.					
$20	$8.00	$5.60	$3.20	$0.80	......	......
$22	10.00	7.60	5.20	2.80	$0.40	......
$24	12.00	9.60	7.20	4.80	2.40	......
$26	14.00	11.60	9.20	6.80	4.40	$2.00
$28	16.00	13.60	11.20	8.80	6.40	4.00
$30	18.00	15.60	13.20	10.80	8.40	6.00
$32	20.00	17.60	15.20	12.80	10.40	8.00
$34	22.00	19.60	17.20	14.80	12.40	10.00
$36	24.00	21.60	19.20	16.80	14.40	12.00
$38	26.00	23.60	21.20	18.80	16.40	14.00
$40	28.00	25.60	23.20	20.80	18.40	16.00

[1] Cost of lumbering, including logging and milling costs and depreciation.
[2] Figured by the formula: $S = F - (1 + \text{rate of interest}) \text{ times } C$, where S=stumpage value, F=f. o. b. mill value, and C=cost of lumbering.

From the standpoint of management the value of second-growth stands is the important thing, and this in turn depends largely on the proportion of grades which any particular stand will cut. Table 19 indicates the proportion of the different grades cut from second-growth white ash under 75 years of age of different diameters from comparatively straight and sound trees, such as would be grown in properly managed second-growth stands. The second half of this table shows mill-run value f. o. b. mill per 1,000 board feet of trees of different diameters, taking the following f. o. b. mill prices for the different grades:

	Firsts and seconds.	No. 1 common.	No. 2 common.	No. 3 common.
High	$60	$35	$25	$15
Average	50	30	20	10
Low	40	25	15	5

TABLE 19.—*Proportion of different grades cut from white ash trees of different diameters, from comparatively straight and sound trees under 75 years old, and value f. o. b. mill of the lumber which could be produced from them.*

Diameter breast high.	Grades of lumber.				F. o. b. mill value per 1,000 board feet.		
	Firsts and seconds.	No. 1 common.	No. 2 common.	No. 3 common.	High.	Average.	Low.
Inches.		*Per cent.*	*Per cent.*	*Per cent.*			
8		53	34	13	$29.00	$24.00	$19.00
10	1	51	41	7	29.75	24.70	19.65
12	7	47	40	6	31.55	26.20	20.85
14	22	42	30	6	35.30	29.20	24.10
16	29	42	22	7	38.65	32.20	25.75
18	35	39	19	7	40.75	33.70	26.95
20	43	36	15	6	42.75	35.90	28.75

Stated in general terms, the mill-run value of second-growth ash from comparatively straight and sound trees of all three commercial species ranges about as follows:

Size of trees in diameter breast high.	Value f. o. b. mill per 1,000 board feet of lumber.		
	Low.	Average.	High.
7–11 inches	$20	$24	$29
12–16 inches	24	29	36
17–21 inches	28	34	40

Taking $14 as an average cost for logging and milling, allowing 20 per cent for profit, and using the average values given above, would give average stumpage values as follows:

Size of trees in diameter breast high.	Average stumpage value per 1,000 board feet.
7–11 inches	$7.20
12–16 inches	12.20
17–21 inches	17.20

Probably a record price for ash stumpage was paid in 1913 in east-central Illinois (near the Indiana line) when $32 per thousand board feet was paid for a quarter million feet of old-growth white ash, while on the same tract $125 per thousand board feet was paid for black walnut, $24.75 for white oak, and $18.05 for hickory.

SUMMARY OF IMPORTANT POINTS.

Ash lumber is an extremely valuable wood for special uses. The supply of standing ash timber is becoming limited, and to maintain enough to meet the demand commercial growing of ash is necessary.

The following are the uses for which standing ash timber containing various kinds of material is most suitable and profitable:

1. Clear, rapid-growing second-growth timber of white, green, blue, and Biltmore ash. The wood is straight grained and strong. Trees less than 15 inches in diameter are most valuable for fork, hoe, shovel, spade, and scythe handles (snaths), baseball bats, and singletrees and doubletrees. Trees 15 inches and over in diameter are valuable for the above uses and for boat oars, wagon tongues, lumber for bent wood, other parts in car and vehicle construction, and sporting and athletic goods.

2. Large, clear, old-growth ash timber of all species holds its shape well and is especially valuable for dimension lumber (largely for resawing) for car and boat construction, interior finish, church, store, and office fixtures, vehicle and automobile bodies, and agricultural and musical instruments. (See Pl. III.)

3. Crooked and knotty ash timber and small, slow-growing trees (such as are found on poor, thin soils producing weak wood) and the lower grades of ash lumber can best be used for butter-tub staves and heading, woodenware, and novelties, chair and furniture stock, hames, and other uses in which short, clear pieces, such as can be cut out from between knots, can be utilized.

4. Clear black ash timber over 15 inches in diameter, the supply of which is very limited, is especially valuable for butter-tub hoops, splints for baskets, and chair bottoms, and for interior finish.

The owner of ash timber who wishes to sell it will find it advisable:

(1) To determine for what uses it is most valuable; (2) to get in touch with local firms who handle ash or consume it in these uses; (3) to write to State forestry officials or to the Forest Service, Washington, D. C., for wood-using reports which give the names and addresses of firms in the various industries which consume ash; (4) to select names of firms in industries using ash as one of the chief woods, and find out by correspondence which of them is in the market for ash; (5) to write to these firms stating what ash is for sale, and ask them for specifications in regard to the clearness, size, shape, and grade of the material which they wish to purchase, and for prices on such material either standing or in log f. o. b. local station, or sawed into special forms.

APPENDIX.

CLASSIFIED USES OF ASH IN DIFFERENT WOOD-USING INDUSTRIES.

1. HANDLES.

Axe; broom and mop; cant hook; carrying (for pianos); cultivator; D-fork; D-shovel; D-spade; edge tool; engravers' tool; file; grubbing hoe; hammer; hand drill; hand spike; hatchet; hay fork; hay knife; hoe; ice hook; jack; manure fork; maul; mop; oyster tongs; paint brush; peavy; pick; pole brush; potato hoe poles; pump; rake; scoop; shovel; snath; snow shovel, spade; spade; stable forks; tool (small and large); torch; track tool; trowel.

2. DAIRY SUPPLIES.

Butter packages; butter tubs (staves, heading, and hoops); butter paddles and workers; cheese boxes; churns and churn parts.

3. VEHICLES AND VEHICLE PARTS.

[In automobiles, buggies, bobsleds, carriages, gocarts, pushcarts, sleighs, sleds, trucks, wagons, and wheelbarrows.]

Bentwood for bows; bodies, frames, beds, and sears (including sills, running boards, panels, slats, sides, tops, footboards, gates, and braces); hounds—spring bars, tongue hounds, front and rear hounds, and bolsters; poles, shafts, and tongues; pungs and pung frames; reachers and risers; rims or felloes, and spokes; single and doubletrees, and eveners; sled and sled runners; yokes.

4. PLANING-MILL PRODUCTS, SASH, DOORS, AND BLINDS, AND GENERAL MILL WORK.

Baselvards; beams (for ceilings, etc.); blinds; brackets; cabinetwork; casing (for door and window); colonades; colonial columns; consoles; corner blocks; doors; door jambs; finish; flooring; frames, window; interior trim; lath; nosing; panels; partition; plate rails and racks; railing; rosettes (wall and stair); sash; screens; siding; sills; shelving; stair (string boards); veneered panels; wainscoting; wainscot rail; window aprons; weather stripping.

5. REFRIGERATORS AND KITCHEN CABINETS.

Ice boxes; ice chests; kitchen cabinets; refrigerators.

6. CAR CONSTRUCTION.

[Passenger, Pullman, and street cars, locomotive cabs, freight and dump cars.]

Boxes (casting for controller box); boxes (roller sign for electric cars); bulkheads (passenger cars); carlins (on electric cars); chair arms (railway cars); covers (switch boxes on electric cars); car blocking; cornice posts; cupboard doors (on railway cars); dust guards; facing window partition; frames, window; framework (trolley cars); interior finish; panels; partitions; posts; rafters; seats (electric cars); vestibules; wainscoting; windows.

7. FURNITURE.

Antique furniture; beds, folding; bed slats; benches (mess); benches (piano); bookcases; book racks; buffets; bureaus; cabinets (music); camp furniture; castors; chamber suits; chiffoniers; china closets; commodes; couch frames and poles; cradles, baby; davenports; desks; drawer sides and bottoms; dressers; frames for parlor furniture; hall racks; lawn furniture; lodge furniture; magazine racks, school furniture; settee hammocks; sideboards; sofas; tables, extension, kitchen, library, mess (in boats), sewing, telephone; table slides; table legs; table tops; umbrella stands; wardrobes; washstands.

8. AGRICULTURAL IMPLEMENTS.

Corn huskers; corn planters; corn shellers; cotton planter parts; cradles, grain; cultivator beams; feeders; fingers, grain cradle; grain drills, feeders, and separators; harrows; harvesters; hay presses; hayloader parts; hayrack parts; hoppers, fruit and vegetable; manure spreader parts; peanut picker parts; peanut planter; plow handles; plow poles; plow rungs and pins; rake teeth; reaper slats; roller frames; rollers; seeding machine (pan sides, riddles); shredder; stacker parts; thills, seeder; thrasher; windwill parts; windmills.

9. BOXES AND CRATES.

Basket hoops; baskets; baskets, slat; baskets, split; box ends; boxes, ammunition; boxes, comb; boxes, creamery shipping; boxes, ditty; boxes, knife; boxes, medicine; boxes, mill and supply; boxes, salt; boxes, tinplate; boxes, woven splint; crates, vegetable; crating.

10. SHIP AND BOAT BUILDING.

Boat frames; cabins, interior; canoe decking; canoes; coaming, motor boat; covers, hatchway (ship); finish, trimming; grilles (ship and boat cabins); keels, motor boat; knees; launches; oars, boat; paddles; rails, yacht; ribs (boat and canoe); stays, boat; stems (boat and canoe); tillers; wheels, pilot.

11. SPORTING AND ATHLETIC GOODS.

Balls; baseball bats; billiard cues; billiard rails; croquet sets; fishing rods; gymnasium goods; hockey sticks; parallel bars; pike poles; polo sticks; skis; sleds; snowshoes; spring bars; tennis rackets; toboggans.

12. FIXTURES.

Cabinets; cabinets, medicine; cases, show; cases, lining; church fixtures; church pews; counter tops; display racks; drafting tables; frames, show-case; shelves, store fixtures; stanchions.

13. CHAIRS.

Chair backs; chair bottoms; chair frames; chair legs; chair posts (bent and straight); chair rockers; chair seats; chair-wheel parts; chair-cushion frames; kitchen chairs; stools.

14. MUSICAL INSTRUMENTS.

Actions, piano; banjo; drums; harps; moldings (piano); organ frames; organs; pipe-organ casting; pipe organs; piano backs; piano bottom boards; piano cases; piano facings; piano fronts; piano keys; piano keyboards; piano pilasters; piano players (inside work); piano tops; talking machines; tambourines.

15. WOODENWARE AND NOTIONS.

Blackboards, children's; bottoms, dry measure; buckets (sugar, jelly); carving boards; cattle guards; clothes bars; cloth boards; coffee mills; curtain pole, swing cleats; door knobs; doorstops; drain boards; drawer stops; fish nets; frames (coal, gravel, sand screens); frames (cutter); frames, roller; frames, sieve; heading (nail keg); hoops, bucket; hose, menders; kegs, putty; kegs, spice; ladder rounds; ladders; ladders, extension; lard tubs; measures; pails, candy; plane bodies; planks (fish, steak); plugs; reels, garden hose; rollers, towel; signaling devices.

16. SADDLES AND HARNESS.

Fillers, scotch hame; neck yoke; saddletrees; saddles; yokes.

17. MACHINE CONSTRUCTION.

Cylinders (cider mill); cylinders (flour mill); loom parts; machinery (flour mill); machinery (gin); parts, engine; parts, road machinery; sawmills (portable); scroll-saw tops; well-digging machine.

18. PUMPS.

Pump rods; sucker rods; well machinery.

19. TOYS.

Toys; hobby horses; toy automobiles; toy rakes; toy shovels; toy wagons.

20. PLUMBERS' WOODWORK.

Toilet seats; toilet tanks; sink drain boards.

21. TRUNKS.

Trunk slats; trunk strips; trunks.

22. PULLEY AND CONVEYORS.

Brake blocks; tackle blocks; timber grapples; wood pulleys.

23. PICKER STICKS AND BOBBINS.

Bobbins; picker sticks.

24. PRINTING MATERIAL.

Cabinets, printers'; cases, printers'; press platforms; printing-press forms; printers' supplies.

25. PICTURE FRAMES AND MOLDING.

Mirrors; molding, picture.

26. CARPET SWEEPERS.

Boxes, carpet sweepers; parts, carpet sweepers.

27. PLAYGROUND EQUIPMENT.

Playground apparatus; lawn swings; porch swings.

28. ROLLERS, SHADE AND MAP.

Rollers, shade and map; venetian blinds.

29. ELEVATORS.

Cars (dumb waiter); cars, elevator; dumb waiter (cleats, battery); flooring, cars (passenger and freight); frames (elevator cars); gates; grain elevators; guide posts (dumb waiter); strips (elevator cars).

30. INSTRUMENTS, PROFESSIONAL AND SCIENTIFIC.

Army supplies; boxes, miter; chests (draftsman's); firearms; litters (Army); medicine cases; tripods.

31. LAUNDRY APPLIANCES.

Clothes racks; frames, curtain; frames, wash tray; frames, wash tub; washboards; washing machines; washing-machine rubbers; washing-machine tops.

32. MACHINERY AND ELECTRICAL APPARATUS.

Electrical apparatus, parts; battery boxes.

33. MINE EQUIPMENT.

Lagging; stone boats.

34. BRUSHES.

Brush backs.

35. PATTERNS AND FLASKS.

Brick molds; pattern machine parts; patterns.

36. WHIPS.

Whip handles.

37. DOWELS.

Dowels.

38. CASKETS AND COFFINS.

Coffins.

39. BUTCHERS' BLOCKS AND SKEWERS.

Fixtures, butchers'; supplies, butchers'.

40. AEROPLANES.

Frames; propellers.

41. WEIGHING APPARATUS.

Scales.

42. GATES AND FENCING.

Fencing; pickets.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 524

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

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DETECTION OF LIME USED AS A NEUTRALIZER IN DAIRY PRODUCTS.

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CONTENTS.

INTRODUCTION.

The use of lime by central-station creameries before pasteurization for the purpose of reducing the acidity of cream before churning has assumed considerable proportions. The cream is bought directly from farmers at the various cream stations and then shipped in an unneutralized state to the centralizing creamery to be manufactured into butter. On arrival it is graded into two classes, according to its taste and smell rather than its acidity. As the cream often has been shipped several hundred miles to the central plant, it frequently arrives in a very old and sour state, sometimes with an acidity of over 1 per cent lactic acid. Cream with a "bad" taste or foreign odor is churned into second-grade butter. If the cream is too sour, lime is added in order to reduce the acidity to 0.3 or 0.4 per cent lactic acid. The creameries claim to be able to make a good grade of butter even from a very sour cream by the use of lime, and the butter thus made is said to grade a number of points higher than that made from the same cream not neutralized. Hence it has become a common practice, especially in summer when it is difficult to

NOTE.—This bulletin will be useful to officials of State dairy and food departments.

prevent excessive souring, to "lime" or "neutralize" cream of high acid content, before pasteurization, in order to reduce its acidity and improve the salable quality of the butter made from it. Some creameries use sodium carbonate for this purpose instead of lime.

The work reported in this bulletin was undertaken for the purpose of developing and perfecting a method for detecting with certainty the addition of lime to cream before its manufacture into butter. It is believed that no such method has heretofore been published. The detection of alkali salts when used to neutralize dairy products has not been considered in this publication but has been left for future work. Nor has any consideration been given to the question of possible detriment to health, or to the legal, economic, and ethical phases of the process discussed in this bulletin.

Milk and products derived from milk contain calcium phosphate as one of the principal constituents of the ash. Leach[1] states that the percentage of calcium oxid in the ash of a typical milk is 20. Blyth[2] gives figures ranging between 17.31 and 27.55 with a mean of 22. Tibbles[3] quotes an analysis by Schrodt wherein the calcium oxid is 21.45 per cent of the ash. König[4] gives a figure of 22.42 per cent. Köstler[5] reports values for the percentages of calcium oxid in the ash of milk, cream, buttermilk, and butter. His maximum and minimum figures are given in Table 1.

TABLE 1.—*Percentages of calcium oxid in the ash of dairy products, as calculated by Köstler.*

Substance.	Number of analyses.	Calcium oxid in ash.	
		Maximum.	Minimum.
		Per cent.	*Per cent.*
Milk	10	24.63	22.24
Skimmed milk	1	24.48	....
Cream	1	23.09	....
Buttermilk	19	24.54	21.22
Butter	11	22.83	20.07

Shaffer and von Fellenberg[6] found values between 18.3 and 20.2 per cent for butter.

[1] Leach, Albert E., Food Inspection and Analysis, 3d ed., p. 128, New York, 1913.

[2] Blyth, A. W. and M. W., Foods: Their Composition and Analysis, p. 201, London, 1909.

[3] Tibbles, William, Foods, Their Origin, Composition, and Manufacture, p. 245, London, 1912.

[4] König, J., Chemie der Menschlichen Nahrungs- und Genussmittel, 4th ed., v. 2, p. 603, Berlin, 1904.

[5] Köstler, G. Zur Charakterisierung unserer schweizerischen Butterarten. *In* Landw. Jahrb. der Schweiz, 25 (1911), 249–276.

[6] Shaffer, F., and von Fellenberg, Th. Zur Unterscheidung der Butterarten. *In* Mitt. Lebensm. Hyg., 2 (1911), 220.

While it is probable that the percentage of calcium oxid in the ash of pure cream and butter would correspond closely to the figures quoted above, it is important to prove this point before proceeding with the interpretation of analyses of commercial milk products to determine whether lime may have been added.

METHODS OF ANALYSIS.

Samples of milk, buttermilk, or cream require no particular preparation for analysis. All samples of butter analyzed in this investigation were prepared in the following way: About 1 pound of butter was melted at as low a temperature as possible in a well-stoppered, wide-mouthed bottle and then cooled. The melted fat, curd, water, and salt were violently shaken together before and during the "setting" of the butter. If the sample subsequently is kept cool, it will not leak buttermilk, thus causing variations in sampling.

In order to prove the addition of lime to dairy products a careful analysis of the ash is essential. To determine total ash, 10 grams of milk, cream, or butter are weighed out in a platinum dish, the water evaporated on a steam bath or air oven, the fat then burned off, and the dish heated in a muffle at a low heat until a white ash remains. The water must be completely evaporated before the fat is ignited, otherwise there will be loss by spattering. In the case of salted butter, after weighing the ash add dilute nitric acid and determine the sodium chlorid by precipitation with silver nitrate. All results reported in this bulletin were determined gravimetrically, with the exception of alkalinities. Unless the percentage of salt is more than 5 it is best determined without taking an aliquot. The difference between the total ash and the sodium chlorid in the ash is the salt-free ash. In duplicate determinations there may be a noticeable difference in the total ash, but the percentages of salt-free ash agree very closely. Examples of some of the results obtained are given in Table 2. No effort was made to select especially favorable results.

TABLE 2.—*Agreement in percentages of salt-free ash in dairy products.*

Sample No.	Total ash.	Salt.	Salt-free ash.	Sample No.	Total ash.	Salt.	Salt-free ash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	2.117	2.004	0.113	6	3.430	3.285	0.1[illegible]2
	2.066	1.956	.110		3.400	3.258	.142
2	3.887	3.735	.152	7	3.840	3.694	.146
	3.863	3.718	.145		3.840	3.700	.140
3	4.860	4.660	.200	8	4.784	4.654	.130
	4.779	4.577	.202		4.758	4.629	.129
4	4.768	4.647	.121	9	4.780	4.620	.160
	4.640	4.518	.122		4.808	4.644	.164
5	4.847	4.675	.172	10	4.822	4.721	.101
	4.870	4.693	.177		4.753	4.655	.098

The salt-free ash in duplicate analyses should agree within 0.01 per cent, and further analysis should be made if the results do not agree within this limit.

Disagreements in the total ash are considered as due to volatilization of sodium chlorid at different temperatures of ignition and not to variation in sampling. If the differences were due to variation in sampling the ash of unsalted butter should show the same relative discrepancies. To show that this is not the case, ash percentages of three unsalted butters are given as follows:

TABLE 3.—*Agreement in ash percentages of unsalted butters.*

Sample No. 1.	Sample No. 2.	Sample No. 3.
Per cent.	*Per cent.*	*Per cent.*
0.139	0.202	0.088
.141	.204	.087
.137	.205	.086

The differences between triplicate determinations are well within the 0.01 per cent limit.

The amount of sample to be used in making the calcium oxid determinations will depend on the capacity of the dishes available or the quantity of ash present. In the experiments subsequently reported the ash of from 10 to 50 grams of sample was used, treated as follows: A known quantity of decinormal hydrochloric acid was added, warmed to dissolve the ash, and after cooling the solution was titrated back with decinormal sodium hydroxid to obtain the alkalinity, using Methyl Orange as the indicator. Acetic acid was then added in slight excess and the calcium precipitated from hot solution with ammonium oxalate. After standing overnight, preferably on a warm steam bath, the calcium oxalate was collected on a small filter, washed free from chlorid, and ignited to constant weight as calcium oxid. The volume of solution when filtered should not be over 100 cc. Under conditions of slight acidity and small volume the error in the calcium determination, due to the solubility of calcium oxalate in acetic acid solution, is negligible. When iron or aluminum is present the ferric or aluminum phosphate, being insoluble in acetic acid, must be filtered off before the precipitation with ammonium oxalate. Practically, this is necessary only in those cases where cream or butter has become contaminated with iron from the container. Leach[1] gives the percentage of iron oxid in the ash of milk as 0.13 and makes no mention of aluminum. The average ash of milk is 0.71 per cent, cream has less ash, depending on the amount of fat, and the ash of unsalted but-

[1] Leach, Albert E., Food Inspection and Analysis, 3d ed., p. 128, New York, 1913.

ter is usually less than 0.2 per cent. The amount of iron or aluminum found in the ash of uncontaminated products in the amounts taken for analysis is negligible. The following data, taken at random from a large number of determinations, show how closely duplicate determinations of calcium oxid will check:

TABLE 4.—*Agreement in percentages of calcium oxid in ash of dairy products.*

Percentage of CaO.	Percentage of CaO.	Percentage of CaO.	Percentage of CaO.	Percentage of CaO.
0.0360	0.0500	0.0575	0.0637	0.0772
.0372	.0500	.0600	.0642	.0765
.0410	.0280	.0356	.0425	.0567
.0405	.0285	.0340	.0410	.0562

These figures show that with careful work results can be obtained that check considerably within 0.003 per cent; 0.01 per cent for salt-free ash and 0.003 per cent for calcium oxid are considered the maximum differences allowable.

Samples of milk collected in Denver gave figures comparable to those found in the literature, as shown in Table 5.

TABLE 5.—*Analysis of Denver milks.*

Constituent.	Jersey milk.	Holstein milk.	Unknown milk.
Fat (per cent)	4.50	3.30	4.00
Ash (per cent)	0.80	0.75	0.73
Alkalinity of ash (cc N/10 acid per 100 grams)	78.00	66.50	68.50
Calcium oxid in milk (per cent)	0.194	0.165	0.17
Calcium oxid in ash (per cent)	24.26	22.00	23.30

ANALYSIS OF UNNEUTRALIZED CREAMS.

Analyses of a considerable number of creams received by local creameries were made at the Denver laboratory of the Bureau of Chemistry during the summer of 1913. The samples of cream, the ash data of which are given in Table 6, were secured before neutralization.

TABLE 6.—*Analysis of ash of Denver creams before liming.*

Ash.	Ash on fat-free basis.	Alkalinity of ash on fat-free basis.[1]	CaO in cream.	CaO in ash.	CaO on fat-free basis.
Per cent.	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
0.42	0.73	71.6	0.100	23.7	0.174
.47	.72	68.5	.106	22.5	.163
.51	.79	68.5	.105	20.5	.163
.44	.71	64.5	.100	22.7	.161
.49	.76	68.7	.111	22.6	.173
.35	.56	51.4	.077	22.0	.123
.45	.74	69.5	.100	22.0	.165
.46	.66	56.4	.102	22.1	.147
.45	.71	65.7	.100	22.2	.158
.31	.53	54.6	.077	24.8	.133
.40	.63	71.0	.095	23.7	.150
.39	.66	57.9	.088	22.5	.150
.31	.53	55.2	.077	25.0	.133
.39	.72	....	.091	23.3	.168
.46	.73	58.4	.111	24.1	.177
.36	.65	60.6	.085	23.6	.154
.40	.72	73.5	.097	24.3	.175
.44	.75	67.1	.100	22.7	.172
.45	.77	60.6	.104	23.1	.179
.48	.64	60.8	.117	24.3	.158
.62	.83	78.4	.144	23.2	.193
.50	.75	76.5	.120	24.0	.181
Average..0.43	0.69	66.3	0.100	23.1	0.161

[1] Cc N/10 acid per 100 grams (Methyl Orange, indicator).

From the figures given in Table 6 it would appear that the following are conservative maximum values for unneutralized cream:

Alkalinity of ash on fat-free basis (cc N/10 acid per 100 grams) 80.00
CaO in cream on fat-free basis (per cent) 0.20
CaO in ash (per cent) 25.00

ANALYSIS OF DAIRY PRODUCTS MADE FROM UNNEUTRALIZED CREAMS.

A number of analyses of butter churned from unneutralized cream were made at the Denver laboratory during the year 1913. The ash data are given in Table 7.

TABLE 7.—*Analyses of ash of butter made from unneutralized cream. 1913.*

Alkalinity of ash.[1]	CaO in butter.	Salt-free ash.	CaO in salt-free ash.
	Per cent.	*Per cent.*	*Per cent.*
12.0	0.026	0.13	20.0
13.3	.026	.16	16.3
10.6	.024	.12	20.0
14.5	.030	.15	20.0
8.5	.017	.07	24.2
......	.027	.14	19.3
17.5	.030	.14	21.4
13.0	.037	.15	24.6
15.0	.059	.24	24.5
10.0	.020	.10	20.0
11.0	.021	.09	23.3
12.0	.026	.13	20.0
15.0	.036	.15	24.0
12.0	.021	.11	19.1
15.6	.032	.14	23.5
Average..12.8	029	.134	21.3

[1] Cc of N/10 acid per 100 grams (Methyl Orange, indicator).

Inspectors in the western district of the bureau sent to the Denver laboratory, during the summer of 1914, a number of salted and unsalted butters made from unneutralized cream. Samples of salt used in their manufacture also were analyzed. These samples were obtained from the States of Washington, Oregon, Colorado, New Mexico, and Arizona, and can be regarded as authentic. The data obtained are given in Table 8.

TABLE 8.—*Analyses of salted and unsalted butters made from unneutralized cream. 1914.*

Salt.	Salt-free ash.	CaO in butter.	CaO in salt-free ash.	Alkalinity.[1]	CaO in salt.
Per cent.	*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*
......	0.102	0.021	20.5	9.0	....
2.45	.126	.025	20.2	12.0	0.105
......	.092	.015	16.3	7.5	....
2.72	.134	.025	18.6	12.0	.370
......	.106	.021	20.1	9.5	....
4.28	.116	.020	17.2	11.0	0.0
......	.108	.026	23.9	10.5	....
3.49	.124	.031	25.0	13.5	.406
2.63	.114	.026	22.8	12.5	.360
......	.079	.018	22.7	8.0	....
4.85	.135	.030	22.2	12.0	.20
......	.075	.018	24.0	7.5	....
2.26	.137	.030	22.2	9.5	Unknown.
2.67	.140	.022	15.7	13.5	.193
1.78	.072	.018	25.0	9.5	.120
3.04	.088	.022	25.0	13.0	.140
......	.095	.021	22.1	9.5	....
3.87	.098	.022	23.0	10.0	Unknown.
......	.066	.015	22.7	7.0	....
......	.066	.015	22.7	7.0	....
0.56	.124	.025	20.1	13.0	.162
2.65	.118	.022	18.6	12.0	Unknown.
......	.076	.017	22.3	5.5	....
3.25	.100	.017	17.0	11.0	.056
......	.121	.027	22.3	11.0	....
2.90	.123	.025	20.3	14.0	0.0
......	.100	.019	19.0	10.0	....
2.53	.101	.018	17.8	11.0	.064
......	.106	.023	21.7	9.5	....
1.99	.123	.022	17.8	12.5	.078
3.71	.113	.022	19.4	11.5	.143
......	.098	.016	16.7	9.0	....
5.11	.136	.031	22.8	13.0	.147
......	.116	.026	22.8	10.0	....
Average. 2.98	.107	.022	20.9	10.8	.159

[1] Cc of N/10 acid per 100 grams (Methyl Orange, indicator).

It will be seen from the foregoing table that the calcium oxid in the salt-free ash of butter made from unlimed cream averaged about 21 per cent. This is believed to be a much more reliable determination than is either the alkalinity or the calcium oxid percentage in the entire sample. The alkalinity will vary through a rather wide range in butter, depending upon the care with which the buttermilk is removed. The amount of calcium oxid in the ash of the entire sample will vary with the quantity of buttermilk left in the butter and with the extent of calcium impurities in the salt. On the other hand, the percentage of calcium oxid in the salt-free ash is almost the same irrespective of how completely the buttermilk is removed. In order to test this point, two creams obtained from reliable sources were churned in the laboratory. One was well washed and the other not, the object being to obtain in one case a butter of low ash content and in the other case one of high ash content.

TABLE 9.—*Analyses of samples of two unneutralized creams and of the butter and buttermilk made from them.*

Determination.	Cream.		Butter.		Buttermilk.	
	Sample No. 1.	Sample No. 2.	Sample No. 1.	Sample No. 2.	Sample No. 1.	Sample No. 2.
Fat (per cent)	34.00	25.60				
Ash (per cent)			0.136	0.29	0.715	0.787
Ash on fat-free basis (per cent)	0.75	0.83				
Alkalinity of ash (cc N/10 acid per 100 grams)			15.60	26.40	68.00	73.20
Alkalinity on fat-free basis (cc N/10 acid per 100 grams)	76.50	78.40				
Calcium oxid in entire sample (per cent)			0.032	0.068	0.165	0.186
Calcium oxid on fat-free basis (per cent)	0.181	0.193				
Calcium oxid in ash (per cent)	24.10	23.20	23.50	23.40	23.00	23.80
Moisture (per cent)			15.44	29.80		
Curd (per cent)				1.60		

The results of analysis show that the two creams were normal. The composition of the buttermilk was very similar to that of the cream calculated to a fat-free basis. Calculating the analysis of butter No. 2 to the maximum percentage of moisture allowed (16 per cent),[1] gives:

Moisture (per cent)	16.00
Curd (per cent)	2.97
Ash (per cent)	0.54
CaO in entire sample (per cent)	0.126
CaO in ash (per cent)	23.40
Alkalinity of ash (cc N/10 acid per 100 grams)	49.10

The data presented in Table 9 show that while the percentage of calcium oxid and the alkalinity of the ash may vary considerably in different samples, depending upon conditions, and are therefore unreliable for detecting the practice of liming, even extreme conditions, as in butter No. 2, have no influence on the percentage of calcium oxid in the ash.

INFLUENCE OF LIMING ON COMPOSITION OF DAIRY PRODUCTS.

During the summer of 1913 and the winter of 1914 experiments were conducted in Denver in order to ascertain the influence of liming on the composition of cream, butter, and buttermilk.

[1] U. S. Dept. of Agr., Office of the Secretary, Circ. 19, Standards of Purity for Food Products, p. 7. U. S. Internal Revenue Regulations No. 9, Revised July, 1907, p. 87, state that butter having 16 per cent or more of moisture is classed as adulterated butter.

EXPERIMENTS MADE DURING 1913.

The following experiment was conducted on a commercial scale at one of the Denver creameries in the summer of 1913:

Four hundred gallons of sour cream, weighing 3,230 pounds, were poured into the "dump box." The cream was well mixed by a revolving spiral and a sample of the raw, unpasteurized material was taken from the box. Approximately half of the cream was removed and pasteurized and a sample secured as it ran into the cooling tank. The remainder was treated with slaked lime mixed to a thin paste with water. The proportion of this paste added was about 1 quart to 100 gallons of cream. Samples representing the limed and unlimed parts of the same original lot were taken. The two creams were then run into separate tanks, properly cooled, and transferred into churns. The tanks were washed out with an unknown quantity of water from a hose and this water added to the cream in the churn. After churning, the butter was washed with water and properly drained. Samples were taken of the unsalted and salted butters and of the buttermilks made from the two varieties of cream. Samples of the salt used in the manufacture of the butters also were secured. This work was repeated in part at a later date. Two hundred gallons of cream were dumped, 1 quart of lime mixture added, and the cream pasteurized. Samples of the cream, before and after liming, and of the butter and buttermilk made from the limed cream were collected. The results of the analyses of these samples are given in Table 10.

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TABLE 10.—*Analyses of unlimed and limed dairy products. Denver, summer of 1913.*

Description of sample.	Acidity (phenolphthalein, indicator).	Fat.	Ash.	Ash on fat-free basis.	Salt.	Salt-free ash.	Alkalinity of ash (Methyl Orange, indicator).	Alkalinity of ash on fat-free basis.	CaO in entire sample.	CaO on fat-free basis.	CaO in salt-free ash.	CaO in ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Cc N/10 acid per 100 grams.*	*Cc N/10 acid per 100 grams.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Unlimed cream:												
Before pasteurization	0.62	35.70	0.45	0.70	...	...	...	70.00	0.105	0.163	...	23.30
After pasteurization	.60	36.30	.47	.73	...	...	...	74.50	.112	.175	...	23.80
From dump box, experiment No. 2	.54	37.90	.455	.73	...	...	...	75.60	.115	.185	...	25.20
Limed cream:												
Before pasteurization	.43	35.70	.59	.91	...	...	...	110.40	.190	.295	...	32.20
After pasteurization	.32	35.00	.57	.87	...	...	...	103.10	.187	.287	...	32.80
Experiment No. 2	.40	37.30	.54	.86	...	...	...	96.40	.165	.263	...	30.30
Butter from unlimed cream:												
Unsalted	...	82.82	.108	...	...	...	8.00	...	.023	...	...	21.40
Salted	...	79.16	4.276	...	4.14	0.136	10.40	...	.030	...	22.00	...
Butter from limed cream:												
Unsalted	...	83.00	.122	...	...	...	11.20	...	.034	...	...	27.80
Salted	...	77.74	4.544	...	4.39	.154	12.80	...	.042	...	27.20	...
Experiment No. 2	...	84.36	.14	...	...	...	13.20	...	.038	...	...	27.10
Buttermilk from unlimed cream	.70	...	.71	...	...	...	60.50	...	.147	...	...	20.70
Buttermilk from limed cream	.48	...	.76	...	...	...	82.00	...	.225	...	...	29.60
Experiment No. 2	.55	...	.84	...	...	...	84.00	...	.225	...	...	26.60
Salt used in butter	...	...	...	...	...	...	...	...	.190	...	...	...

This experiment shows that when lime is added to the raw material there is a considerable rise in the alkalinity of the ash and in the percentages of ash, calcium oxid, and calcium oxid in the ash, of both the limed cream and the resulting butter. In comparison with the values given in previous tables the percentage of calcium oxid in the ash or salt-free ash, as the case may be, seems most significant. Although the greater part of the added lime is removed in the buttermilk as calcium lactate, enough remains to cause a very appreciable increase in the percentage of calcium oxid in the salt-free ash. The analyses of the buttermilks do not correspond entirely to those of the respective creams on the fat-free basis because of the dilution with water, but the resemblance is very noticeable.

EXPERIMENTS MADE DURING 1914.

During the winter of 1914 additional data were obtained bearing on the composition of limed dairy products. These figures differ from those given in Table 10, for the reason that they were obtained from cream delivered in the winter. This cream, for obvious reasons, is not subject to spoilage in the same degree as commercial cream produced in the summer season and, consequently, its acidity is lower. It was desired to ascertain whether the addition of small amounts of lime could be detected. In the tabulated data the amount of lime added to the cream is not stated, because, in accordance with the usual practice, it was not gauged, but was stirred with water after slaking and then poured into the sour cream, the operator being guided by experience and by his sense of taste and smell as to the quantity necessary. The volume of liquid added, therefore, is no criterion of the quantity of lime introduced. That the quantity added was very small is shown by the slight reduction of the acidity. The data obtained are given in Tables 11 and 12.

TABLE 11.—*Analyses of unlimed and limed dairy products. Denver, winter of 1914. Plant No. 1.*

Product.	Acidity (phenolphthalein, indicator).	Fat.	Ash.	Ash on fat-free basis.	Salt.	Salt-free ash.	Alkalinity of ash (Methyl Orange, indicator).	Alkalinity of ash on fat-free basis.	CaO in entire sample.	CaO on fat-free basis.	CaO in salt-free ash.	CaO in ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Cc N/10 acid per 100 grams.*	*Cc N/10 acid per 100 grams.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Unlimed products:												
Cream, raw	0.34	35.80	0.447	0.696	......	......	44.00	68.50	0.105	0.164	......	23.30
Starter	.72	1.20	.765	.774	......	......	71.50	72.30	.183	.185	......	23.90
Cream and starter	.37	32.50	.474	.702	......	......	45.00	66.60	.112	.166	......	23.70
Unsalted butter	......	......	.120	......	......	......	11.00	......	.026	......	......	22.00
Salted butter	......	......	5.130	......	5.01	0.12	9.00	......	.027	......	22.50	......
Buttermilk	.51	.60	.645	......	......	......	58.00	......	.152	......	......	23.60
Salt	......	......	......	......	......	......	......	......	.177	......	......	......
Limed products:												
Cream, raw	.35	......	......	......	......	......	......	......	......	......	......	......
Cream, limed, No. 1	.30	35.10	.456	.702	......	......	46.50	71.60	.116	.178	......	25.30
Starter No. 1	.72	1.20	.765	.774	......	......	71.50	72.30	.183	.185	......	23.90
Starter No. 2	......	1.15	.764	.772	......	......	73.00	73.80	.183	.185	......	23.90
Limed cream No. 1 plus starter No. 1	.34	31.10	.495	.719	......	......	47.50	68.90	.127	.184	......	25.60
Limed cream plus starter No. 2[1]	......	26.50	.580	.789	......	......	61.50	83.60	.162	.220	......	27.90
Unsalted butter No. 1	......	......	.140	......	......	......	13.50	......	.035	......	......	25.00
Unsalted butter No. 2	......	......	.145	......	......	......	14.00	......	.041	......	......	28.20
Salted butter No. 1	......	......	4.790	......	4.67	.12	11.50	......	.031	......	25.80	......
Salted butter No. 2	......	......	4.940	......	4.83	.11	14.00	......	.032	......	29.00	......
Buttermilk No. 1	.58	.60	.707	......	......	......	66.00	......	.177	......	......	25.00
Buttermilk No. 2	......	.75	.761	......	......	......	78.00	......	.215	......	......	28.20
Salt	......	......	......	......	......	......	......	......	.177	......	......	......

[1] Samples of raw and limed cream before the addition of starter were not obtained.

TABLE 12.—*Analyses of unlimed and limed dairy products. Denver, winter of 1914. Plant No. 2.*

Product.	Acidity (phenolphthalein, indicator).	Fat.	Ash.	Ash on fat-free basis.	Salt.	Salt-free ash.	Alkalinity of ash (Methyl Orange, indicator).	Alkalinity of ash on fat-free basis.	CaO in entire sample.	CaO on fat-free basis.	CaO in salt-free ash.	CaO in ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Cc N/10 acid per 100 grams.*	*Cc N/10 acid per 100 grams.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Unlimed products:												
Cream, pasteurized	0.31	35.60	0.434	0.683			39.00	60.50	0.101	0.157		23.20
Starter	.81	4.20	.750	.780			69.00	72.00	.189	.197		25.20
Cream plus starter	.36	33.20	.447	.669			42.50	63.60	.106	.158		23.70
Unsalted butter			.120				12.00		.024			20.00
Salted butter			5.370		5.25	0.12	13.50		.023		19.10	
Buttermilk	.45	.60	.669				57.00		.150			22.40
Salt									Trace.			
Limed products:												
Cream, raw	.38	37.60	.460	.73			38.00	60.90	.102	163		22.40
Cream, limed	.30	38.00	.465	.75			45.50	73.30	.129	.208		27.70
Starter	.89	4.00	.747	.77			74.00	77.10	.181	.188		24.30
Limed cream plus starter	.39	34.00	.509	.77			50.00	75.70	.136	.206		25.70
Unsalted butter			.150				13.00		.041			27.30
Salted butter			5.040		4.96	.08	9.50		.022		28.10	
Buttermilk [1]	.48	.20	.890				71.50	72.60	.198			22.20
Salt									Trace.			

[1] This buttermilk has an undue amount of ash and a low percentage of calcium oxid in ash. The alkalinity of the ash and the percentage of CaO in the entire sample are normal. The sample may have been contaminated with a little ash material such as salt.

The maximum limits previously given for alkalinity and calcium oxid in unneutralized cream were exceeded in these two plants in only one and two cases, respectively. These limits, therefore, can not be depended upon to detect slight liming. The percentage of calcium oxid in the ash, however, shows clearly the addition of lime to the cream, even when the reduction of acidity of the cream, due to lime, is only 0.05 per cent.

As the same salt was used in both the limed and unlimed butter at each plant, any effect that the impurities of the salt might have would apply in the same degree to both kinds of butter.

ANALYSES OF BUTTER PROBABLY MADE FROM NEUTRALIZED CREAM.

In Table 13 are given a number of analyses of butters which, interpreted in the light of experimental data so far obtained, are believed to have been made from limed cream. Some of the analyses represent butter made by creameries which admit that they use lime as a neutralizer. Those marked with an asterisk are authentic samples collected by inspectors of the bureau.

TABLE 13.—*Analyses of butters believed to have been made from limed cream.*

Salt.	Salt-free ash.	CaO in butter.	CaO in salt-free ash.	Alkalinity (Methyl Orange, indicator).	CaO in salt.
Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Cc N/10 acid per 100 grams.*	*Per cent.*
*3.45	0.131	0.045	34.3	14.0	0.142
*3.99	.101	.026	26.2	11.5	.085
*3.25	.238	.096	40.3	28.0	.192
*......	.206	.090	43.8	25.0	....
......	.100	.032	32.0	14.0	....
......	.140	.041	29.6	14.7	....
......	.150	.045	30.0	17.5	....
......	.100	.030	30.0	17.5	....
......	.110	.035	31.8	17.5	....
......	.140	.040	28.5	15.0	....
......	.120	.033	27.5	12.0	....
......	.140	.054	38.5	20.0	....
......	.180	.056	31.1	17.0	....
Average....	.142	.048	32.5	17.2	....

It can be seen readily from the above figures that the butters represented by these analyses are of a very different character from those given in Tables 7 and 8 and from the unlimed samples recorded in Tables 10, 11, and 12. An inspection of the various tables will show that although the determinations of alkalinity and of calcium oxid in the entire sample may indicate liming, they can not be relied on altogether, as the figures for limed and unlimed butter will often overlap, depending on factors met with in manufacturing. The percentage of calcium oxid in the ash or in the salt-free ash will reveal the liming, even if it be but slight.

EFFECT OF IMPURITIES IN THE SALT ON THE PERCENTAGE OF CALCIUM OXID IN THE SALT-FREE ASH.

CALCIUM SULPHATE.

The most usual impurity in dairy salt and the one present in greatest quantity is calcium sulphate. The amount of salt-free ash in butter will increase with the calcium content if salt containing calcium sulphate is used, but it will not increase in the same ratio. The calcium oxid percentage in calcium sulphate is 41, in the ashes of dairy products it averages about 22 per cent. This difference will cause an increase in the calcium oxid percentage in the salt-free ash, the amount of increase depending upon the quantity of salt used and the amount of impurity in it.

Street[1] found in 21 samples of salt examined, from 0.30 to 1.23 per cent of calcium sulphate and from 0 to 0.35 per cent of calcium chlorid. Woll[2] found in domestic brands of dairy salt percentages of calcium sulphate ranging from 0.31 to 1.87 per cent and of calcium chlorid from 0.02 to 0.65. The maximum allowances for table or dairy salt that have been established by the Department of Agriculture are: 1.4 per cent for calcium sulphate and 0.5 per cent for calcium chlorid plus magnesium chlorid.[3]

To ascertain the effect of impurities in the salt upon the percentage of calcium oxid in the salt-free ash, a number of experiments were made. Four unsalted stock butters, A, B, C, and D, were used for this purpose. About 5 pounds of butter were melted and well shaken during solidification. Portions of 200 grams were withdrawn and melted in a bottle with 10 grams of salt of known composition. The butter and salt were well mixed by shaking during solidification. The butter treated in this manner contained approximately 4.75 per cent of salt. This is more salt than the average American creamery butter contains, but it was thought best to work with quantities higher than the average so that a certain amount of margin for variation might be provided.

The methods employed in the analysis of butter thus treated were the same as those given on page 3. Figures for sulphur trioxid, calculated to calcium sulphate, are also included. In some cases the sulphate was determined by dissolving the ash of 40 grams of butter in dilute hydrochloric acid and then precipitating with barium chlorid. In other cases 100 grams of butter were melted and extracted with 50 cc portions of warm water acidulated with hydro-

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[1] Street, J. P. Thirteenth Report on Food Products. *In* Conn. Agr. Exp. Sta. Biennial Rpt., 1907–08, Pt. IX, p. 595.

[2] Woll, F. W. A Study of Dairy Salt. *In* Wis. Agr. Exp. Sta. Bul. 74, pp. 12–13, May, 1899.

[3] U. S. Dept. Agr., Office of the Secretary, Circ. 19, Standards of Purity for Food Products, p. 19.

chloric acid. The water extract was cooled and made up to 250 cc, after adding some pure cupric chlorid or mercuric bichlorid solution to precipitate the proteins. Two hundred cc of the clear filtrate were treated with barium chlorid as in the usual sulphate determination. The results are given in Table 14.

TABLE 14.—*Analyses of butters mixed with salt of known composition, showing the effect of impurities on the percentage of calcium oxid in the salt-free ash.*

Stock sample.	Salt added to butter.	Composition of salt.	CaO in butter.	SO_3, calculated as $CaSO_4$[1].	SO_3, calculated as $CaSO_4$[2].	Salt-free ash.	CaO in salt-free ash.	CaO in salt-free ash corrected for $CaSO_4$ in salt[3].	CaO in salt-free ash corrected for $CaSO_4$ in salt[4].
	Grams to 100 grams.	*Per cent.*	*Per ct.*	*Per cent.*	*Per cent.*	*Per ct.*	*Per ct.*	*Per cent.*	*Per cent.*
A	0	......	0.0177	0.002	......	0.087	20.3	......	......
B	0	......	.0275	......	......	.139	19.7	......	......
C	0	......	.0400	.005	......	.204	19.6	......	......
[5] D	0	......	.0504	......	......	.150	33.6	......	......
A	5	C. P.	.0170	.005	......	.099	17.1	......	......
B	5	do	.0250	......	......	.134	18.6	......	......
C	5	do	.0366	.003	......	.176	20.8	......	......
D	5	do	.0460	......	......	.142	32.4	......	......
B	1	do	.0252	......	......	.142	17.7	......	......
C	1	do	.0372	......	......	.179	20.8	......	......
A	5	0.296 $CaSO_4$	.0238	.014	......	.121	19.7	17.0	......
A	5	0.505 $CaSO_4$	.0282	......	......	.129	21.6	17.4	......
C	5	0.505 $CaSO_4$	.0500	.014	......	.197	25.3	24.1	......
A	5	1.067 $CaSO_4$	.0383	......	......	.162	23.6	......	......
C	5	1.067 $CaSO_4$	.0587	.037	......	.218	26.7	23.7	......
A	5	1.427 $CaSO_4$	.0452	.063	......	.173	25.5	17.3	......
B	5	1.427 $CaSO_4$	.0550	.061	0.070	.202	27.2	21.2	19.7
C	5	1.427 $CaSO_4$	.0640	.055	......	.231	27.7	23.4	......
A	5	2.097 $CaSO_4$	.0565	.094	......	.201	28.1	16.7	......
B	5	2.097 $CaSO_4$	.0665	.090	.103	.229	29.0	21.1	19.2
C	5	2.097 $CaSO_4$	.0768	.079	......	.262	29.3	24.2	......
B	2.5	2.097 $CaSO_4$	.0443	.034	......	.184	24.0	20.1	......
C	5	0.20 $CaCl_2$	.0421	......	......	.177	23.7	......	......
B	5	0.42 $CaCl_2$	.0352	......	......	.140	25.1	......	......
C	5	0.42 $CaCl_2$	.0480	......	......	.181	26.5	......	......
B	5	0.63 $CaCl_2$	.0410	......	......	.144	28.5	......	......
C	5	0.63 $CaCl_2$	.0524	......	......	.185	28.3	......	......
B	2.5	0.63 $CaCl_2$	.0333	......	......	.139	24.0	......	......
B	5	1.43 $CaSO_4$ 0.47 $CaCl_2$	.0620	.062	.072	.207	30.0	25.1	24.0
B	2.5	1.43 $CaSO_4$ 0.47 $CaCl_2$	.0440	.025	......	.174	25.1	22.6	......
D	5	1,00 Na_2SO_4	.0435	......	......	.172	25.3	......	......
D	5	0.93 $MgCl_2$	.0443	......	......	.148	30.0	......	......
[6] D	5	[6] 1.22 $CaCl_2$ 0.51 $MgCl_2$	.0643	......	......	.141	45.6	......	......

[1] Determined in ash.
[2] Determined in water extract.
[3] Determined from SO_3 in ash.
[4] Determined from SO_3 in water extract.
[5] Sample D was a butter made from a limed cream.
[6] A visible precipitate of $MgNH_4PO_4$ was obtained from the ash of 20 grams of butter from 100 cc of solution.

An inspection of Table 14 reveals a number of interesting points. The first one noted is the change in the percentage of calcium oxid in salt-free ash when chemically pure salt is added. This change seems to depend upon the quantity of butter ash. If the quantity present is low the change is minus, becoming a plus with the higher quantities of ash. The reason for this has not been determined but it is probably due to conditions of ashing. With higher quantities of ash this action seems to decrease materially. Since this change would, in the majority of cases, give the benefit of any doubt to the manufacturer, it is not thought to be of any serious consequence.

Table 14 also shows that relatively high percentages of salt, contaminated to a considerable degree, must be added before the percentage of calcium oxid in the salt-free ash of butter made from unneutralized cream will exceed 25, the tentative maximum limit. If only 2.5 per cent of salt, the average quantity present in American butter, is added, the salt may contain about 2 per cent of calcium sulphate before the limit is reached. Furthermore, a correction for calcium sulphate in the salt can be applied by determining the sulphate in the butter. The sulphate found is calculated to calcium sulphate and this figure subtracted from the salt-free ash. The equivalent amount of calcium oxid is subtracted from the total calcium oxid, and the quotient of these corrected figures gives the actual percentage of calcium oxid in the salt-free ash. The determination of the sulphate in the acidulated water extract is preferable to the ashing method, as the results are higher owing to the well-known action of phosphorus pentoxid in driving out sulphur trioxid unless sufficient alkali is present. This action is especially strong in sample C, because of its higher ash and consequently higher phosphorus pentoxid content. It is possible that better results would be obtained by the ashing process if sodium carbonate were first added, but since the extracting process is just as quick, it appears to be preferable. The amount of sulphates in the ash of unsalted butter or butter salted with chemically pure salt, derived from the sulphur of the casein, is so slight as to be negligible. In the extract method it would be removed by the protein precipitant.

CALCIUM CHLORID.

When salt is contaminated with calcium chlorid the action is somewhat different. The calcium chlorid does not increase the salt-free ash because it is almost equivalent to the two sodium chlorid molecules calculated from the silver chlorid precipitate. Therefore, the calcium oxid is increased without corresponding increase in the salt-free ash, causing an increase in the percentage of calcium oxid in the salt-free ash. With about 5 per cent of salt in the butter it requires an impurity in the salt of approximately 0.4 per cent calcium chlorid before the percentage of calcium oxid in the salt-free ash of the butter will reach the limit of 25. Salt to the amount of 2.5 per cent, when added to butter, may contain about 0.65 per cent of calcium chlorid, the maximum amount in dairy salt as found by Woll,[1] without causing errors in interpretation. No correction for calcium chlorid can be applied.

[1] Woll, F. W. A Study of Dairy Salt. Wis. Agr. Exp. Sta. Bul. 74, p. 13, May, 1899.

Analyses made by the water laboratory of the Bureau of Chemistry of samples of salt collected from representative markets of the United States showed but very small percentages of calcium chlorid, magnesium chlorid, or sodium sulphate, the main impurity being calcium sulphate. However, within a radius of 200 miles from Cincinnati, a salt is produced and consumed largely locally that contains no sulphate and relatively large percentages of calcium and magnesium chlorids ($CaCl_2$, 0.9 to 2.3 per cent; $MgCl_2$, 0.3 to 0.8 per cent). Table 14 shows that the effect of adding this salt to butter is to increase greatly the percentage of calcium oxid in the salt-free ash. An unneutralized butter might, therefore, occasionally be classed as neutralized if highly salted with salt contaminated with considerable calcium chlorid. Analyses of butter, particularly if the butter is produced in the above locality, must be scrutinized with special care if they show no sulphate. Magnesium chlorid is associated with calcium chlorid in Ohio salt, and an increase in the magnesium oxid percentage in butter salted with it might be expected. Leach[1] states that the magnesium oxid content of the ash of milk is only 2.42 per cent. The maximum amount of magnesium oxid that could be present in 50 grams of butter, therefore, would be only about 2 milligrams. Any increase could be regarded as due to impurities in the salt, and a high percentage of calcium oxid in the salt-free ash would thus be explained. However, this salt is to be found only in a very limited area, and the amount of butter affected thereby is exceedingly small compared with the total product of the United States. The effect of calcium chlorid, therefore, may be considered practically negligible except in a very few special cases.

CALCIUM SULPHATE AND CALCIUM CHLORID.

If both calcium sulphate and calcium chlorid are present, their effect is cumulative. In Table 14 is shown a case where about 5 per cent of salt which contained the maximum amount of calcium sulphate and calcium chlorid allowed in dairy salts[2] was used in salting the butter. The percentage of calcium oxid in the salt-free ash reached 30, but when the effect of the calcium sulphate was calculated, though retaining the effect of the calcium chlorid, it dropped to 24, 1 per cent below the maximum. When 2.5 per cent of this salt of maximum allowed impurity was employed, the percentage of calcium oxid in the salt-free ash was only 25, without any correction for calcium sulphate.

MAGNESIUM CHLORID.

Should salt containing magnesium chlorid be used the percentage of calcium oxid in the salt-free ash of the butter would be lowered

[1] Leach, Albert E., Food Inspection and Analysis, 3d ed., p. 128, New York, 1913.

[2] U. S. Dept. of Agriculture, Office of the Secretary, Circ. 19, Standards of Purity for Food Products, p. 19.

because of an increase in the salt-free ash without a corresponding increase in the calcium oxid in the butter. In the ashing process the magnesium chlorid is decomposed with loss of chlorin and the salt-free ash is increased by the equivalent magnesium oxid. This point is well illustrated in Table 14. But it would be only in the case of a butter salted with large quantities of salt of exceptionally high magnesium chlorid content that a serious lowering of the calcium oxid determination would result in a butter made from neutralized cream being classed as made from unneutralized cream.

SODIUM SULPHATE.

The use of salt contaminated with compounds other than calcium chlorid or calcium sulphate causes a lowering of the percentage of calcium oxid in the salt-free ash. Sodium sulphate, for example, increases the salt-free ash without increasing the calcium oxid. If it were known that the salt used contained sodium sulphate its effect could be calculated as easily as that of calcium sulphate. Fortunately, the amount of impurities other than calcium salts in American dairy salt is small and their effect is almost negligible.

INTERPRETATION OF RESULTS.

The figure 25 as the maximum percentage of calcium oxid in the salt-free ash of unneutralized butter is considered a good working standard. It allows considerable latitude for the effect of calcium impurities in the salt. If the CaO figure of any particular butter is below 25, the butter may immediately be classed as made from unlimed cream.

If the brand of salt used in the manufacture of any given sample of butter could be ascertained the interpretation of results of analysis would be greatly simplified. Analyses of the most widely used brands of American dairy salt would be useful in connection with this work.

Butters with a percentage of calcium oxid in the salt-free ash of between 25 and 28 should be classed as suspicious. After correction has been made for calcium sulphate, determined from the sulphate present, if the percentage of calcium oxid in the salt-free ash is still above 25, the butter was made from a limed cream. If the CaO figure drops from above 25 to below 25, the apparently high percentage was caused by the calcium sulphate in the salt used, and the butter must be considered as made from unlimed cream. A butter which contains more than 28 per cent of calcium oxid in the salt-free ash, especially when the percentage of salt or sulphate is low, can be identified as made from a neutralized cream. A sulphate determination should be made on all butters which show a CaO figure above

25, and the proper correction applied. It may be assumed safely that all the sulphate is present as calcium sulphate, as the amount of sulphates other than calcium in salt is usually very small. Correction may not always give absolutely true values, but in the majority of cases the results are probably well within the limits of error of the work. The limit of 25 is not to be considered as an arbitrary rule that may not be altered by future work, but rather as a fair maximum standard, especially after correction is made for calcium sulphate in the salt, and one that should give the manufacturer the benefit of any doubt.

USE OF LIME TO RENOVATE OLD STORAGE BUTTER.

While cooperating with the Denver internal revenue office another use of lime as a neutralizer was detected. Upon applying the spoon test for renovation on some samples of butter submitted by the revenue agent, a very peculiar reaction was noticed. The butter when heated formed a foam similar in appearance to that observed when glucose is heated for ashing purposes. Instead of forming large bubbles which broke quickly, these samples produced a foam with very small bubbles, which held up for an unusual length of time and emitted a strange, sweetish odor when heated. Upon factory inspection it was found that the firm making the product examined was using lime to sweeten and deodorize old storage butter. It was essentially a chemical renovation process. Frozen storage butter was broken into a tank containing slaked lime and water and was allowed to "temper" for about 12 hours. The product was then removed, washed, worked over, and sold as creamery butter.

In Table 15 are given the data collected on this variety of butter.

TABLE 15.—*Analyses of storage butters renovated by the use of lime.*

Sample No.	Alkalinity.	CaO in butter.	Salt-free ash.	CaO in salt-free ash.
	Cc N/10 acid per 100 grams.	*Per cent.*	*Per cent.*	*Per cent.*
3053-E	102.0	0.282	0.40	70.5
3054-E	26.6	.069	.15	46.0
3055-E	62.0	.174	.29	60.0
3057-E	21.5	.069	.19	36.3
3063-E	29.0	.085	.20	42.5
3064-E	....	.080	.20	40.0
5533-E	67.0	.180	.32	56.2
5534-E	68.0	.175	.31	56.4
5553-E	97.5	.275	....	....
5554-E [1]	297.0	.840	....	....
5555-E [1]	341.0	.940	....	....
5566-E	26.5	.078	.17	45.8
5567-E	29.0	.083	.18	46.1
5568-E	....	.190	.33	57.5
5569-E	....	.146	.25	58.4
5570-E	28.5	.080	.17	47.0
5571-E	28.5	.086	.21	40.9

[1] Butter mixed with lime water taken from tank in which the butter was neutralized.

All the butters, the analyses of which are given in Table 15, were alkaline to litmus to a greater or less degree, and had a peculiar foam test and a sweetish smell on heating, especially those of high lime content. When heated with dilute sulphuric acid all of them gave a more or less distinct smell of butyric acid, thus indicating the presence of calcium butyrate. The water extracts of these butters were alkaline to litmus paper and those containing the larger quantities of calcium oxid were alkaline to phenolphthalein. Some of these samples have been kept for months in an ice-box without developing the characteristic smell of rancid butter, although many became moldy and possessed a bad odor. When the butter was treated with hot alcohol, as in the determination of acids in fats, considerable acidity was usually found, indicating the presence of free oleic and palmitic acids.

The liming of cream is a renovation of a deteriorated intermediate product, while the liming of butter is a renovation of a more or less spoiled final product. The chemistry of the two processes is different. The main acid constituent of sour cream is lactic acid, and when lime is added calcium lactate is probably the principal substance formed, but with an excess of lactic acid remaining. When this cream is churned the percentage of calcium oxid in the salt-free ash is increased because of the quantity of calcium lactate remaining in the butter fat. It is probable that with excessive washing these calcium salts could be washed out, but with the calcium would go the flavor, a property the creamery man desires to keep in his product as its value depends upon it, in large measure. Since the lime is never added in excess, the butter will give a more or less acid reaction to litmus paper.

Storage butter is always acid even when not rancid. When it is placed in a lime solution the free water-soluble acids that may be present are neutralized to a greater or less degree. Since these acids are perhaps one of the main causes of bad odor in rancid butter, their neutralization will sweeten and deodorize the product. The nonvolatile, nonsoluble acids, oleic and palmitic, play only a secondary part in this process. These acids and their calcium salts are practically insoluble in water and would be neutralized only in small part. By using alcohol their presence in the free state can be demonstrated. The calcium salts of the offensive water-soluble volatile acids are more or less soluble in water and are removed partly in the subsequent washing, the amount which remains depending on the extent of the washing. Their presence can be demonstrated by their odor on adding dilute sulphuric acid. Nor is the excess of calcium hydroxid entirely removed, for all of the water extracts of these butters gave an alkaline reaction to litmus. When such butter is ashed the added calcium salts will cause an increase in the alkalinity of the ash, and especially in the percentage of calcium oxid in the salt-free ash. It should be noted, however, that the alkalinity of a butter made from limed cream, or even of one washed in lime water, might be less than that of a natural butter with a high whey content, but an increase in the percentage of calcium oxid in the salt-free ash would at once reveal the use of lime at some stage. Perhaps by determining the ratio of alkalinity to another constituent of the butter ash, for example, phosphorus pentoxid, an independent method might be developed for detecting neutralization. It might be necessary to distinguish between a butter made from limed cream and a butter given a "lime bath." If the alkalinity were below 20, the reaction of a water extract acid to litmus, and the percentage of calcium oxid in the salt-free ash, corrected for calcium sulphate in the salt, well above 25, the use of a limed cream would be indicated. If, on the other hand, a butter had an alkalinity of over 20, if the percentage of calcium oxid in the salt-free ash was over 35, if its water extract was alkaline to litmus, and if it gave a peculiar foam test and liberated butyric acid on the addition of dilute sulphuric acid, it would be strong evidence that lime had been added to the butter and not to the cream.

SUMMARY.

The percentage of calcium oxid in the ash of milk, unneutralized cream, and butter made from unneutralized cream varies within fairly narrow limits, with a tentative maximum set at 25.

When lime has been added to the cream in the process of manufacture this percentage is increased above 25, the increase varying with the amount of lime added and the degree of washing.

The effect of calcium impurities in the salt has been studied and a method developed to correct for the chief impurity, calcium sulphate.

It has been shown that the percentage of calcium oxid in the salt-free ash of butter made from unneutralized cream will not exceed the tentative maximum limit of 25, unless high percentages of salt with much impurity are employed.

Finally, attention has been called to a form of sophistication of butter by chemical renovation.

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EXPERIMENTS IN THE DETERMINATION OF THE DIGESTIBILITY OF MILLETS.

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CONTENTS.

INTRODUCTION.

In the study of the digestibility of the nonsaccharine grain sorghums, the results of which were reported in an earlier paper,[1] it was found that the carbohydrates were as completely utilized as those of the more common cereals—wheat, corn, oats, etc.—while the protein of the sorghums was much less available to the human body than that of the better-known cereals. This paper reports the results of a similar study of the digestibility of two millets, common millet (*Setaria italica*) and proso (*Panicum miliaceum*), which are grown in this country and which are of interest because of the possible extension of their use. These grains have been little used for human food in this country, although the latter is receiving considerable attention in some sections. In Russia it is reported[2] that the yearly per capita consumption of proso is 30 pounds; in oriental countries, especially among the poorer people, both of these cereals have been at times extensively employed in the dietary and are staple and well-known grains.

[1] U. S. Dept. Agr. Bul. 470 (1916), Studies on The Digestibilty of the Grain Sorghums.
[2] Inaug. Diss., Imp. Mil. Med. Acad. [St. Petersburg], 1887. [Russian.]

NOTE.—This is a technical report of studies of the digestibility of millet in relation to its use as food and is of special interest to investigators and students of human nutrition.

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A survey of the literature revealed little except empirical information as regards the digestibility and nutritive value of millets. Kurcheninov[1] studied the digestibility of proso, employing five men (physicians and dispensary assistants) of normal health as subjects, for experimental periods of three days each. He prepared the meal, which comprised 63 per cent of the entire grain, by mixing with water and cooking in the form of a thin gruel and a thick mush; the protein of the basal ration, consisting of bouillon, butter, white bread, and cutlets, was found to be 91 per cent utilized, but when the gruel and mush were eaten in conjunction with the basal ration the protein utilization became 43.4 per cent and 43.9 per cent, respectively.

According to Church,[2] the group of cereals which he designates as millets, including common millet and proso, are very important food crops in India. He states that common millet, although it may contain as much as 8 per cent crude fiber in the unhusked grain, is generally considered nutritious and digestible, and that it is prepared by boiling and eaten with or without the addition of sugar, or by parching. Proso is boiled and eaten with sugar and milk, used in curries, or in a form in which the slightly boiled grain is dried, parched in hot sand, sifted from the husks, and eaten with sour milk.

As the millet meals were not found in the open market, a sufficient quantity of millet and proso for the purpose of the investigations was obtained from the Bureau of Plant Industry and ground in the experimental mills at the Bureau of Chemistry. The attempt was made to grind the millets to the same degree of fineness as the sorghum meals used in the experiments referred to, but this was difficult, since the millets have a tough, woody, outer husk, relatively larger in amount than that of the common cereals. When the meal was sifted for bread making (using an ordinary flour sieve of 16 meshes per inch) 40 per cent of millet and 29 per cent of proso (chiefly bran) were removed, quantities much larger than was the case with the other grains previously studied. In other words, the yield of meal of the same degree of fineness as that obtained with the sorghums was smaller.

PREPARATION OF FOOD.

The millets do not contain gluten and so, used alone, are not suitable for making leavened bread. They can, however, be used for making unleavened bread and, in general, like the grain sorghums, are similar to corn meal in the ways they can be prepared for the table rather than to wheat and rye.

[1] Inaug. Diss., Imp. Mil. Med. Acad. [St. Petersburg], 1887. [Russian.]

[2] Food-grains of India. London: Chapman and Hall, Limited, 1886, 1901.

It was found that a bread resembling corn cake, but with molasses and a little ginger added to give flavor, was satisfactory for experimental purposes. The ingredients and proportions used in preparing the millet bread were as follows: Fifteen cups of meal, 3¾ teaspoons of salt, 3¾ teaspoons of soda, 5 teaspoons of ginger, 1⅞ cups of molasses, 1 scant cup of shortening (lard), and 2 quarts of hot water. The ingredients were thoroughly mixed and baked for 1½ hours in a moderate oven. The bread prepared according to this method was largely crumb, having only a thin but very hard crust.

The basal ration was so chosen as to contain a minimum amount of protein in order that the larger proportion of this constituent would be derived from the millet. As in earlier tests, it consisted of boiled potato, fruit (orange), and sugar. The subjects were allowed to drink tea or coffee without milk or cream, if they wished, and, of course, all the water desired. The bread was baked each day and accordingly was always served fresh. A quantity of potato sufficient to supply all the subjects for the entire experimental period was boiled and mashed. Sometimes the subjects warmed the potato before eating it and sometimes not.

ANALYTICAL METHODS.

Samples of the bread were analyzed. The composition of the potato, of the fruit (which furnished a very small proportion of the total protein), and of the sugar was computed from average figures.[1] The feces resulting from the test periods was freed from water by drying at 95° C., then weighed, pulverized, thoroughly mixed, and sampled. The analytical methods followed were those recommended by the Association of Official Agricultural Chemists.[2]

DETAILS OF THE DIGESTION EXPERIMENTS.

The subjects were urged to eat liberally of the bread and were allowed to eat of the accessory foods served, as they desired. However, the amount of potato served was small, in order that only a relatively small amount of potato protein would be consumed. No attempt was made to have all the subjects eat equal amounts; their preferences varied in some instances quite widely. The food eaten by each was weighed in separate portions, and after each meal any which remained uneaten was also weighed, the difference between these two representing the amount eaten.

Five young men (medical and dental students), who had gained experience in other investigations of like character and had shown themselves trustworthy, served as subjects in this investigation. All were in good health and reasonably active and, so far as could be

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[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 28 (1906).
[2] U. S. Dept. Agr., Bur. Chem. Bul. 107 (1907).

judged, had no digestive abnormalities. During the experimental period they were requested to observe their usual routine as regards amount of exercise taken, hours of eating, etc. Because of their interest in the study of physiology and their previous experience in this type of work they were sufficiently informed of the nature of their duties to appreciate the importance of carefully following the directions given them.

For the purpose of identifying the feces of the experimental period, three or four gelatin capsules containing about 0.3 gram each of pulverized charcoal were taken with the first meal of the experimental period and with the first meal following the test period. The separation of the feces due to the diet under investigation was easily made at the line of demarcation between the portion colored by the charcoal and the lighter portion due to the ordinary food.

The subjects were allowed to follow their customary dietary routine before and after the experimental periods. Since this study of millet is concerned with the coefficients of digestibility only, no attempt was made to maintain a nitrogen equilibrium or to maintain uniform body weight of the subjects. The urine resulting from the experimental periods was not collected, for it was considered that any constituents of the food which had been sufficiently broken down to appear in the urine had undergone the process of digestion.

In this study a determination has been made of the digestibility of protein, fat, carbohydrates, and ash of the entire ration, and the digestibility of the protein and carbohydrates of the bread alone has been estimated by a method commonly employed in investigations of this character, which consists of making proper allowance for the amount of undigested residue occurring from the various constituents of the diet other than bread. The following equations will serve to indicate the method by which this allowance has been made:

[Weight of protein in potato, butter, and fruit] × [Per cent of undigested protein occurring in each] = [Weight of undigested protein present in feces derived from basal ration].

[Total undigested protein in feces] − [Undigested protein in feces from basal ration] = [Undigested protein occurring from bread].

[(Total protein of bread) − (Undigested protein from bread)] ÷ [Total protein of bread] = [Estimated percentage digestibility of protein in bread alone].

The factors used in the above equations for estimating the coefficients of digestibility of the protein and carbohydrates of bread alone have been determined in previous investigations as being for the protein of potatoes, 83 per cent;[1] of butter, 97 per cent;[1] and of fruit, 85 per cent;[1] while the digestibility of carbohydrates in

[1] Connecticut Storrs Sta. Rpt. 1899, p. 104.

potatoes and fruit has been found to be 95 per cent[1] and 90 per cent,[1] respectively.

The details of the digestion experiments are recorded in the following tables, which include the kind, amount, and total weight of different foods eaten by each subject, the weight of the various constituents of the foods, the weight of the feces, the amount of food utilized, the coefficients of digestibility of the entire ration, and the estimated digestibility of the bread alone.

Data of digestion experiments with millet in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 425, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Bread	1,299.0	324.7	130.7	98.9	688.7	56.0
Potato	624.0	471.1	15.6	.6	130.4	6.3
Fruit	964.0	859.9	2.9	3.9	95.4	1.9
Butter	413.0	45.4	4.1	351.1		12.4
Sugar	72.0				72.0	
Total food consumed	3,372.0	1,701.1	153.3	454.5	986.5	76.6
Feces	199.0		104.4	15.1	58.9	20.6
Amount utilized			48.9	439.4	927.6	56.0
Digestibility of entire ration (per cent)			31.9	96.7	94.0	73.1
Estimated digestibility of bread alone (per cent)			22.6		94.0	
Experiment No. 426, subject A. J. H.:						
Bread	1,244.0	311.0	125.1	94.7	659.6	53.6
Potato	647.0	488.5	16.2	.6	135.2	6.5
Fruit	792.0	706.4	2.4	3.2	78.4	1.6
Butter	364.0	40.1	3.6	309.4		10.9
Sugar	82.0				82.0	
Total food consumed	3,129.0	1,546.0	147.3	407.9	955.2	72.6
Feces	173.0		90.8	19.8	44.9	17.5
Amount utilized			56.5	388.1	910.3	55.1
Digestibility of entire ration (per cent)			38.4	95.1	95.3	75.9
Estimated digestibility of bread alone (per cent)			30.0		95.6	
Experiment No. 427, subject R. L. S.:						
Bread	1,102.0	275.5	110.8	83.9	584.3	47.5
Potato	215.0	162.3	5.4	.2	44.9	2.2
Fruit	892.0	795.6	2.7	3.6	88.3	1.8
Butter	197.0	21.7	2.0	167.4		5.9
Sugar	87.0				87.0	
Total food consumed	2,493.0	1,255.1	120.9	255.1	804.5	57.4
Feces	156.0		79.1	18.2	40.4	18.3
Amount utilized			41.8	236.9	764.1	39.1
Digestibility of entire ration (per cent)			34.6	92.9	95.0	68.1
Estimated digestibility of bread alone (per cent)			29.9		95.3	
Experiment No. 448, subject D. G. G.:						
Bread	1,397.0	366.2	138.9	113.4	722.9	55.6
Potato	549.0	414.5	13.7	.6	114.7	5.5
Fruit	652.0	571.8	2.0	2.6	74.3	1.3
Butter	344.0	37.8	3.5	292.4		10.3
Sugar	162.0				162.0	
Total food consumed	3,104.0	1,390.3	158.1	409.0	1,073.9	72.7
Feces	191.0		92.7	21.2	57.4	19.7
Amount utilized			65.4	387.8	1,016.5	53.0
Digestibility of entire ration (per cent)			41.4	94.8	94.7	72.9
Estimated digestibility of bread alone (per cent)			35.2		94.3	

[1] Connecticut Storrs Sta. Rpt. 1899, p. 104.

Data of digestion experiments with millet in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 449, subject A. J. H.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Bread	1,239.0	324.7	123.2	100.6	641.2	49.3
Potato	539.0	406.9	13.5	.5	112.7	5.4
Fruit	759.0	665.7	2.3	3.0	86.5	1.5
Butter	311.0	34.2	3.1	264.4		9.3
Sugar	131.0				131.0	
Total food consumed	2,979.0	1,431.5	142.1	368.5	971.4	65.5
Feces	176.0		92.0	26.4	37.9	19.7
Amount utilized			50.1	342.1	933.5	45.8
Digestibility of entire ration (per cent)			35.3	92.8	96.1	69.9
Estimated digestibility of bread alone (per cent)			27.5		96.7	
Experiment No. 450, subject R. L. S.:						
Bread	1,549.0	406.0	154.0	125.8	801.6	61.6
Potato	505.0	381.3	12.6	.5	105.5	5.1
Fruit	674.0	591.1	2.0	2.7	76.8	1.4
Butter	281.0	30.9	2.8	238.9		8.4
Sugar	77.0				77.0	
Total food consumed	3,086.0	1,409.3	171.4	367.9	1,060.9	76.5
Feces	140.0		63.4	19.3	39.1	18.2
Amount utilized			108.0	348.6	1,021.8	58.3
Digestibility of entire ration (per cent)			63.0	94.8	96.3	76.2
Estimated digestibility of bread alone (per cent)			60.5		96.9	
Experiment No. 451, subject O. E. S.:						
Bread	1,073.0	281.2	106.7	87.1	555.3	42.7
Potato	691.0	521.7	17.3	.7	144.4	6.9
Fruit	653.0	572.7	2.0	2.6	74.4	1.3
Butter	263.0	28.9	2.6	223.6		7.9
Sugar	165.0				165.0	
Total food consumed	2,845.0	1,404.5	128.6	314.0	939.1	58.8
Feces	128.0		62.4	18.0	33.3	14.3
Amount utilized			66.2	296.0	905.8	44.5
Digestibility of entire ration (per cent)			51.5	94.3	96.5	75.7
Estimated digestibility of bread alone (per cent)			44.6		97.2	
Average food consumed per subject per day	1,000.4	482.7	48.7	122.7	323.4	22.9

Summary.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of protein of bread alone.	Estimated digestibility of carbohydrates of bread alone.
		Protein.	Fat.	Carbohydrates.	Ash.		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
425	D. G. G.	31.9	96.7	94.0	73.1	22.6	94.0
426	A. J. H.	38.4	95.1	95.3	75,9	30.0	95.6
427	R. L. S.	34.6	92.9	95.0	68.1	29.9	95.3
448	D. G. G.	41.4	94.8	94.7	72.9	35.2	94.3
449	A. J. H.	35.3	92.8	96.1	69.9	27.5	96.7
450	R. L. S.	63.0	94.8	96.3	76.2	60.5	96.9
451	O. E. S.	51.5	94.3	96.5	75.7	44.6	97.2
	Average	42.3	94.4	95.4	73.1	35.8	95.7

Data of digestion experiments with proso in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 468, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Bread	1,268.0	441.9	111.0	76.3	602.0	36.8
Potato	591.0	446.2	14.8	.6	123.5	5.9
Fruit	1,075.0	934.2	8.6	2.1	124.7	5.4
Butter	430.0	47.3	4.3	365.5	....	12.9
Sugar	116.0	....	....	....	116.0	....
Total food consumed	3,480.0	1,869.6	138.7	444.5	966.2	61.0
Feces	153.0	....	78.4	16.7	43.9	14.0
Amount utilized	....	....	60.3	427.8	922.3	47.0
Digestibility of entire ration (per cent)	....	....	43.5	96.2	95.5	77.0
Estimated digestibility of bread alone (per cent)	....	....	32.9	....	96.2	....
Experiment No. 469, subject H. R. G.:						
Bread	1,196.0	416.8	104.6	72.0	567.9	34.7
Potato	585.0	441.7	14.6	.6	122.3	5.8
Fruit	993.0	862.9	7.9	2.0	115.2	5.0
Butter	323.0	35.5	3.2	274.6	....	9.7
Sugar	....	....	....	....	....	....
Total food consumed	3,097.0	1,756.9	130.3	349.2	805.4	55.2
Feces	157.0	....	76.3	15.8	52.5	12.4
Amount utilized	....	....	54.0	333.4	752.9	42.8
Digestibility of entire ration (per cent)	....	....	41.4	95.5	93.5	77.5
Estimated digestibility of bread alone (per cent)	....	....	30.7	....	93.9	....
Experiment No. 470, subject A. J. H:						
Bread	980.0	341.5	85.8	59.0	465.3	28.4
Potato	535.0	403.9	13.4	.5	111.8	5.4
Fruit	1,016.0	882.9	8.1	2.0	117.9	5.1
Butter	469.0	51.6	4.7	398.6	....	14.1
Sugar	116.0	....	....	....	116.0	....
Total food consumed	3,116.0	1,679.9	112.0	460.1	811.0	53.0
Feces	132.0	....	57.3	32.4	28.2	14.1
Amount utilized	....	....	54.7	427.7	782.8	38.9
Digestibility of entire ration (per cent)	....	....	48.8	93.0	96.5	73.4
Estimated digestibility of bread alone (per cent)	....	....	37.4	....	98.2	....
Experiment No. 471, subject P. K.:						
Bread	1,539.0	536.3	134.6	92.7	730.7	44.6
Potato	539.0	406.9	13.5	.5	112.7	5.4
Fruit	824.0	716.1	6.6	1.7	95.6	4.1
Butter	392.0	43.1	3.9	333.2	....	11.8
Sugar	15.0	....	....	....	15.0	....
Total food consumed	3,309.0	1,702.4	158.6	428.1	954.0	65.9
Feces	119.0	....	52.0	14.6	40.2	12.2
Amount utilized	....	....	106.6	413.5	913.8	53.7
Digestibility of entire ration (per cent)	....	....	67.2	96.6	95.8	81.5
Estimated digestibility of bread alone (per cent)	....	....	63.9	....	96.6	....
Average food consumed per subject per day	1,083.5	584.0	45.0	140.2	294.7	19.6

Summary.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of protein of bread alone.	Estimated digestibility of carbohydrates of bread alone.
		Protein.	Fat.	Carbohydrates.	Ash.		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
468	D. G. G	43.5	96.2	95.5	77.0	32.9	96.2
469	H. R. G	41.4	95.5	93.5	77.5	30.7	93.9
470	A. J. H	48.8	93.0	93.5	73.4	37.4	98.2
471	P. K	67.2	96.6	95.8	81.5	63.9	96.6
	Average	50.2	95.3	95.3	77.4	41.2	96.2

The total amount of food eaten on the average per subject per day was for the experiments with common millet, 1,000 grams, and with proso, 1,084 grams, which furnished 49 grams of protein, 123 grams of fat, 323 grams of carbohydrates in the millet experiments, and 45 grams of protein, 140 grams of fat, and 295 grams of carbohydrates in the proso experiments. Inasmuch as the subjects ate of the ration according to individual inclination, the heat of combustion varied quite materially—from a maximum of 3,080 calories to a minimum of 2,140 calories per day, as computed by the factors commonly used in the determination of fuel values of foods.

Notwithstanding the quantity eaten, the amount of protein supplied by the ration was low, being on an average less than 50 grams per day, due to the low protein content of the bread prepared from these grains and to its bulky nature.

The values reported for the digestibility of fat of the entire ration more truly represent the digestibility of butter than of the cereal fats, since the latter were present in such relatively small quantities. The values, 94.4 per cent and 95.3 per cent, for the millet and proso rations, respectively, agree with the values for the digestibility of butter reported in connection with a study of the digestibility of hard palates of cattle and in a study of the digestibility of butter, which were 94.6 per cent [1] and 97 per cent,[2] respectively.

The breads made from bolted millet and proso meal do not show a high digestibility for protein in these experiments, the values being 35.8 per cent for millet protein and 41.2 per cent for proso protein. There was no marked difference in the flavor of the millet and proso breads. In India, where they are regarded as important foodstuffs, these grains are commonly boiled, and it is possible that thus prepared they might be more thoroughly digested.

[1] U. S. Dept. Agr., Jour. Agr. Research, 6 (1916), No. 17, p. 647.
[2] U. S. Dept. Agr. Bul. 310 (1915), p. 21.

A small quantity of decorticated millet was tested as to culinary quality, and when boiled the mush was found to be of pleasing flavor. The available quantity was not sufficient for a study of its digestibility.

In discussing the results of experiments with man too much weight should not be given to those obtained with ruminants, but it is not without interest to note that the millet proteins are not as well utilized by the animal body as the proteins of the more common cereals, as indicated by the experiment of Shepard and Koch.[1] Sheep were fed unground grains in connection with a roughage, and it was found that of two varieties of millets the protein was 70 per cent and 55 per cent utilized, while in the case of oats 77 per cent and of corn 78 per cent was utilized by the same sheep under like experimental conditions.

As regards the carbohydrates of millet and proso, it was found in the experiments here reported that this constituent was as well utilized by the subjects as in the case of the more common cereals, the coefficients of digestibility being 95.7 per cent for millet and 96.2 per cent for proso.

In general, therefore, it seems fair to conclude from the data reported that while the millets would contribute somewhat to the protein of the diet, they would be decidedly more important as a source of carbohydrates than of protein. In this they resemble such grains as the sorghums more closely than they do wheat or rye, which are important sources of both protein and carbohydrates.

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[1] South Dakota Sta. Bul. 114 (1909), p. 553. Digestion coefficients of grains and fodders for South Dakota.

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